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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM OF THE

WASHINGTON MEETING

AT THE

BUREAU OF STANDARDS

AND THE

NATIONAL ACADEMY OF SCIENCES

April 28–30, 1932

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The American Physical Society

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APRIL 12, 1932 Vol. 7, No. 2

BULLETIN

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AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, APRIL 28–30, 1932

The 177th regular meeting of the American Physical Society will be held in Washington, D. C., at the Bureau of Standards on Thursday and Friday, April 28 and 29, and at the National Academy of Sciences, B and 21st Streets, on Saturday, April 30, 1932. The first session will be at ten o'clock on Thursday morning.

There will be sessions in the East Building, the Industrial Building and the Chemistry Building at the Bureau of Standards and in the Auditorium and the Lecture Hall of the National Academy of Sciences. The schedule of papers is given in the calendar below.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction, they will be published in an early number of the Physical Review. Authors should send corrections to the Editorial Secretary, the American Institute of Physics, 11 East 38th Street, New York, New York.

Symposium. On Saturday morning, April 30th at 10 o'clock at the National Academy Auditorium there will be a symposium on "*Electric and Magnetic Units.*" This will be followed at 11:15 o'clock by a symposium on "*The Structure of Solids.*"

Dinner. On Friday evening, April 29th, at 7 p.m. there will be a dinner for the members of the Society and their friends, at the Hotel Washington, 15th Street and Pennsylvania Avenue. The price per person will be $2.50. Tickets must be purchased at the registration desk at the Bureau of Standards when registering.

Luncheon. On Thursday and Friday luncheon will be served in the cafeteria at the Bureau of Standards 12:45 o'clock. The price per person will be fifty cents.

Headquarters. The headquarters for the American Physical Society will be the Hotel Washington, 15th Street and Pennsylvania Avenue. Prices for rooms are as follows: single room, $4.00; double bed for two persons, $6.00; twin beds, $7.00. All rooms with bath. Write directly to the Hotel for accommodations.

CALENDAR

Thursday morning

9:00 o'clock: B of S South Building: Conference Room: Council Meeting

10:00 o'clock: B of S Industrial Building: Papers 1–10

10:00 o'clock: B of S Chemistry Building: Papers 11–19

10:00 o'clock: B of S East Building: Papers 20–29

Thursday afternoon

2:00 o'clock: B of S Industrial Building: Papers 30–38

2:00 o'clock: B of S Chemistry Building: Papers 39–45

2:00 o'clock: B of S East Building: Papers 46–55

Friday morning

10:00 o'clock: B of S Industrial Building: Papers 56–66

10:00 o'clock: B of S East Building: Papers 67–74

Friday afternoon

2:00 o'clock: B of S Industrial Building: Papers 75–83

2:00 o'clock: B of S East Building: Papers 84–94

Friday evening

7:00 o'clock: Hotel Washington: Dinner

Saturday morning

10:00 to 11:15 o'clock: N A of S Auditorium: Symposium on "Electric and Magnetic Units." Papers 95–98

11:15 to 12:30 o'clock: N A of S Auditorium: Symposium on "Structure of Solids." Papers 99–100

Saturday afternoon

2:00 o'clock: N A of S Auditorium: Papers 101–108

2:00 o'clock: N A of S Lecture Hall: Papers 109–115

NOTE: The Supplementary Program beginning with No. 116 may be called for at the end of any one of the sessions held in the East Building at the Bureau of Standards or in the Auditorium at the National Academy of Sciences.

New Haven Meeting. The date for this meeting has been set for Thursday, Friday and Saturday, June 23, 24 and 25, 1932. The program has not yet been completely arranged but will include a symposium on "Recent work in the field of x-rays." The Applied Mechanics Division of the A.S.M.E. will hold its meeting in New Haven at the same time and it is possible that there will be a joint session on "Plasticity."

Other meetings for the current season are as follows:

178. June 1932, Pullman, Washington.
179. New Haven, June 23–25, 1932.
180. November 25–26, 1932. Chicago.
181. Pacific Coast. Time and place to be announced later.
182. Annual Meeting. Atlantic City. December 1932.

W. L. SEVERINGHAUS, *Secretary*
Columbia University

April 12, 1932.

PROGRAM

THURSDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

Paper No. 1 will be read by title.

1. The mechanism of atomization accompanying solid injection. R. A. CASTLEMAN, JR., *Bureau of Standards.*—A brief historical and descriptive account of solid injection is followed by a detailed review of the available theoretical and experimental data that seem to throw light on the mechanism of this form of atomization. It is concluded that this evidence indicates that: (1) the atomization accompanying solid injection occurs at the surface of the liquid after it issues as a solid stream from the orifice; and (2) such atomization has a mechanism physically identical with the atomization which takes place in an air stream, both being due merely to the formation, at the gas-liquid interface, of fine ligaments under the influence of the relative motion of gas and liquid and to their collapse under the influence of surface tension to form the drops in the spray. This simple theory, previously proposed by the author, is the most satisfactory and fits the observations the best of any yet advanced. It is recommended that the use of the term "atomization" be restricted to a certain definite range and it is shown that, in this range, its use is sound etymologically and physically, and is descriptive of certain observations. This analysis is to appear in detail as a Technical Report of the National Advisory Committee for Aeronautics.

2. The mechanics of effervescence. OTTO STUHLMAN, JR., *University of North Carolina.*—Bubbles of gas when released in a liquid at depths great compared to their diameters on reaching the surface burst and eject droplets of the fluid into the air. Each bubble whose diameter is less than a critical value, as determined by the characteristics of the liquid, on bursting simultaneously ejects many droplets. Their distribution in height is logarithmic with the greater difference in height between the higher ones. For water at 21°C maximum droplet ejection was 14 cm for a critical bubble diameter of 0.12 cm; benzene is less stable but gives 9.0 cm height for 0.15 cm at 22°C. Bubbles less than 0.10 cm diameter eject droplets to heights proportional to three halves power of the radius. Bubbles having diameters greater than the above critical values burst irregularly. Irregularity is attributed to instability of the bubble. Variation in distribution amongst any given group of droplets at a given height is nearly Maxwellian. Lower boundary is sharp with a more straggling distribution for larger values of height. The theory of ejection herewith developed pictures the bursting bubble accompanied by a gas vortex ring which assists in raising the liquid jet of contour $hx=$constant, and volume $hx^3=c$. Instability in raising a volcano-like jet produces drop formation, which vortex ring redistributes so that log h decreases proportionally as the number of drops increases linearly.

3. Diagonal symmetry in Chladni plates. R. C. COLWELL, *West Virginia University.*—Ritz has shown that all the figures of a Chladni plate may be developed from the equation $w=\Sigma\Sigma u_m(x)v_n(y)$. For high vibrations two terms of the series will give a very close approximation to the sand nodes. The equation then takes the form $w=Au_mv_n+Bu_nv_m$, in which u_m and v_n represent the solutions of a bar fixed at the center. These terms contain both hyperbolic and trigonometric functions. The only diagonal type investigated by Ritz was the simple form where $m=n+1$. This gives one diagonal and a group of wavy lines parallel to it. With an electric valve oscillator which forces the plate into very high vibrations, it is possible to form many complicated figures with symmetry about the diagonal. Several of these will be shown.

4. Ultrasonic absorption in gases. J. C. HUBBARD, *The Johns Hopkins University.*—Electrodes of the piezo-electric plate of an acoustic resonator interferometer (J. C. Hubbard, Phys. Rev. **38**, 1011, (1931)) are connected to the variable capacity of a tuned circuit including

thermo-galvanometer. The circuit is excited at the crevasse frequency of the resonator plate, the circuit being tuned to resonance. Simple relationships are expected and found between thermo-galvanometer current and path-length r in the interferometer fluid. If σ be the ratio of current to resonance maximum current with the interferometer disconnected, σ_0 at loops (constant), σ_m at nodes, then for small values of r $[\sigma_m/(1-\sigma_m)-\sigma_0/(1-\sigma_0)](r\alpha+\beta)=\text{const.}$, where α is the attenuation factor of particle velocity in the fluid, and $\beta=-\log\gamma$, where γ is the coefficient of reflection. Correction must be made when α is large (CO_2). A simple method of evaluating α and γ is derived from peak widths of the σ, r curve. For room air the above relation exactly describes results, but α is several times larger than would be expected for dry, CO_2—free air, being 0.25 at 500 kc and 24°C. Experiments are in progress with pure gases.

5. The electric network equivalent of a piezoelectric resonator. K. S. VAN DYKE, *Wesleyan University.*—The decrement of a quartz resonator is measured by observing in a cathode-ray oscillograph the decay of its free vibrations. The measured logarithmic decrement is a linear function of the external load resistance when electrodes are plated on the quartz, which function yields the resistance and inductance elements of the network. For a quartz rod $40\times5\times5$ mm vibrating lengthwise in its fundamental compressional mode (67.5 kc) the inductance is thus measured to be 490 henries. Comparison of this value with the formulas previously derived (Phys. Rev. **25,** 895, (1925)) for the elements of the network yields a value of the piezo-electric constant for quartz in agreement with Voigt's statically determined value within the limits of error of the experiment. After eliminating the uncertainties of mounting, the decrement is found to be a linear function of the pressure of the surrounding atmosphere and to be proportional to the radiation resistance of the particular gas used. The residual decrement in vacuum for resonance frequencies between 50 and 100 kc varies between 10^{-5} and 5×10^{-5} for different resonators tried. It is 2.5×10^{-5} for the resonator studied above, which indicates a resistance element of 1700 ohms. This corresponds to an internal friction constant (Kimball's ξ, Phys. Rev. **30,** 956 (1927)) of 0.032.

6. Hydrodynamic characteristics of twelve symmetrical hydrofoils. R. C. DARNELL, *U. S. Experimental Model Basin Washington, D. C.*—The center of pressure and coefficients of lift, drag, and absolute moment have been determined for 12 hydrofoils of symmetrical section and 0.25 sq. ft. area at a Reynolds number of approximately 175,000. The hydrofoils were towed (leading edge vertical) in the tank of the Model Basin beneath a special flat bottomed float that carried the dynamometer by which the lift, drag, and torque were measured. The angle of attack was varied from 0° to 45° and the interval between the top of the hydrofoil and the bottom of the float from 0 to 2 in. The aspect ratios studied were 0.5, 1.0, 1.5, and 2.0. In general up to the burbling point the lift coefficient can be represented with fair accuracy by the equation

$$C_L=\frac{\alpha}{0.182+\frac{1}{\pi R}}$$

where α is the angle of attack in circular measure and R the aspect ratio. For $R=1$ the flow breaks down at $\alpha=32°$ and for $R=2$ at about 20°. The center of pressure remains at approximately the quarter chord point up to about 15°; in the interval of 15°—25° it moves rapidly towards the trailing edge and between 25° and 45° is located about 40 percent of the chord from the leading edge.

7. The radom content of soil gas. HOLBROOK G. BOTSET. *Gulf Research Laboratory.—Introduced by Paul D. Foote*—An electroscope and apparatus for sampling and measuring the radon content of soil gas are described. A study of the radon content of soil gases under varying conditions and over extensive areas gave the following results: There is apparently no correlation between radon content and depth from which the gas sample is taken; radon content during rainy weather appears to be higher than in dry weather; certain soil formations appear to have more or less characteristic radon contents. There is great local variation in the radon content of soil gas. Measurement of the radon content over a known salt dome showed a definite

increase in radon content along the edge of the dome. This was an eroded structure and soil along its edge was enriched in heavy mineral. A determination of the heavy mineral content of the soil showed a definite correlation with the radon content of the soil gas, whence it is found that this is an indirect qualitative measure of the heavy mineral content of the soil.

8. Flow of liquids through porous materials under the action of gravity. R. D. WYCKOFF, H. G. BOTSET, M. MUSKAT. *Gulf Research Laboratory.*—Recent published results of studies on the flow of liquids through porous materials under the action of gravity have resulted in rather wide disagreement in both the formulation and interpretation. This paper presents the experimental results obtained by the authors, together with an analysis and final empirical formulation of the flow equations. Typical of the results is the equation for the gravity flow in a radial system given by:

$$Q = \frac{\pi K \gamma g (Z_1^2 - Z_2^2)}{\ln \frac{r_1}{r_2}}$$

where K = permeability of the medium, γ = density of fluid, g = acceleration of gravity, r_1 = reservoir radius, r_2 = well radius, Z_1 and Z_2 = hydrostatic head of fluid observed at the bottom of the sand at r_1 and r_2 respectively. The paper extends the analysis to include the case of composite flow in which gravity and pressure drive exist simultaneously. Experimental data on this case are presented. Finally the analysis is extended to cover general gravity flow systems whose geometry is other than radial.

9. Capillary action at low pressures. F. W. CONSTANT, *Duke University.*—Consideration of the pressure just beneath the meniscus of a liquid in a capillary tube shows that the rise of a liquid due to capillary action is limited at low pressures or for very fine capillaries by the air pressure above the liquid, although the simple theory of surface tension does not predict this. Thus as the air pressure is gradually reduced a capillary column of water, say 30 cm high, is at first unaffected, then falls steadily, showing no rise in a vacuum. This was confirmed experimentally, the effect being somewhat complicated by the slower diffusion of the vapor through the fine capillary. Capillary action in tall trees is hence limited to about 32 feet. No effect occurs for liquids which are depressed in capillary tubes, such as mercury in glass.

10. Viscosity and particle shape in colloid solutions. LARS ONSAGER, *Brown University.*—Einstein has shown that spherical particles in solution will increase the viscosity by a factor $\Delta\eta/\eta = 1 + 2.5\phi$, where ϕ is the fraction of the total volume occupied by the solute. For an extension to ellipsoidal particles, the necessary hydrodynamic calculations have been made by Jeffery (Proc. Roy. Soc. **A102,** 161 (1922)). Presently, the Brownian motion is taken into account. For ellipsoids of rotation, with semi-major axes $a \gg b = c$, the factor 2.5 in Einstein's formula is replaced by $4a^2/15b^2 \log (a/b)$. The time of relaxation for rotation is $\tau = \rho/6kT$, where $\rho = \eta \times 8\pi a^3/3 \log (a/b)$, e.g., $\tau = 10^{-3}$ sec for $\eta = 0.01$ and $a = 100b = 5 \times 10^{-5}$ cm. The calculated viscosities are much greater than those measured by Staudinger for solutions of paraffins, in tetralin, etc., which indicates that such molecules do not retain a straight linear shape in solution. In addition, it seems necessary to assume slip at the surface of a hydrocarbon molecule.

THURSDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

Chemistry Building, Lecture Room

Paper No. 11 will be read by title.

11. The relationship of gravitation and electromagnetism. WILLIAM A. TRIPP, *Medford, Mass.*—The law of gravitation is deduced on a purely electromagnetic basis. The formula for the attractive force between bodies is derived and shown to be equivalent to the usual gravitational formula in the case of bodies at rest, but relative motion affects the value of the force if

the bodies are not at rest. The analysis is based on the present day concept of atomic structure which postulates relatively stationary protons and rapidly moving electrons, coupled with an application of electromagnetic phenomena interpreted in terms of electronic reactions. Gravitation thus appears, not as a vague individual phenomenon, but as the statistical residue of electromagnetic attractions and repulsions on all the individual particles of matter in a body, the attractive forces predominating.

12. Aberration of the second order in the Michelson-Morley experiment. N. GALLI-SHOHAT, *Helen Schaeffer Huff Memorial Research Fellow, Bryn Mawr College.*—The theory of the second-order aberration in application to the Michelson-Morley experiment has been further developed. *Summary.* The phase-effect must be compensated by Lorentz-FitzGerald contraction. The displacement of fringes observed by D. C. Miller is due to aberration of the interfering rays. The horizontal displacement Δl_H of fringes in *D. C. Miller experiment*, recomputed in terms of the horizontal component of v, $\Delta l_H = l/2(v^2/c^2) \sin^2(v_1\, z) \sin 2\psi$, ($z$-vertical, ψ-azimuth), shows a shift of the azimuth-curve by 45°, the velocity v (data of D. C. Miller) is 460 km/sec. in the direction found by D. C. Miller. *Michelson's repetition:* the line of sight l and fringes—stationary; thus, no aberration could be observed. *Joos' repetition:* stationary 1, but rotating fringes; $\Delta l = l/2(v^2/c^2) \sin 2(v_1\, z) \cos\alpha$ (α-angular displacement of fringes) represents a full-period effect, actually observed by Joos but eliminated by averaging the readings for both halves of the interferometer's revolution. *Piccard repetition:* classical form of interferometer, horizontal fringes; thus, full-period vertical effect: $\Delta l_v = l/2(v^2/c^2) \sin^2(v_1\, z) \cos\psi$, again excluded by averaging. *Kennedy's repetition:* photometric method with broad fringes (nearly parallel beams), sensitivity 2×10^{-3} (fringe). In order to detect aberration (about 7×10^{-3} mm), this would require fringes about 4 mm—too narrow for the method used. *Conclusion.* The zero-result of the various repetitions of the Michelson-Morley experiment is *not inconsistent* with the result of D. C. Miller, considered as second-order aberration.

13. Graphical presentation of compressibility data. W. EDWARDS DEMING AND LOLA E. SHUPE. *Bureau of Chemistry and Soils, Washington, D. C.*—By plotting Δ against density in isobars and isotherms, the compressibility data for a gas can be exhibited on a small size graph that renders easy a quick estimation of the remaining p, v, T coordinate when two of them are given. $\Delta \equiv v(pv/RT-1)$. With a little more effort, this coordinate can be calculated accurately by reading the ordinate Δ from the graph at the point corresponding to the two given p, v, T coordinates, and solving for the remaining (unknown) one in $\Delta = v(pv/RT-1)$. This graph thus affords two kinds of interpolation; one is rapid estimation of the unknown p, v, T coordinate, and the other is an easy calculation of its value that gives results as accurately as the original data are known. This method of presentation also shows trends of the deviation from $pv = RT$. Graphs for nitrogen, carbon monoxide, and hydrogen are shown.

14. Transport phenomena in Einstein-Bose and Fermi-Dirac Gases, E. A. UEHLING AND G. E. UHLENBECK, *University of Michigan.*—The theory of gases in non-stationary states, given by Lorentz and Enskog, is generalized for the quantum statistics to give the hydrodynamical equations and the distribution function in first and second approximation, and formal expressions for the viscosity and heat conductivity coefficients. These results are valid for all statistics and for all degrees of degeneration. Two essential points contribute to this generality: (a) Exact expressions independent of statistics and degeneration can be given for the coordinate and time derivatives of the coefficient A of the equilibrium distribution function in terms of the pressure and temperature gradients and time derivatives, though a closed expression for this coefficient as a function of v and T is known only in limiting cases. (b) The function W of the general equation of state for ideal gases in all statistics

$$pv = \frac{RT}{M} W(v^{2/3}T)$$

is adiabatically invariant. Numerical values of the viscosity and heat conductivity coefficients, which should come out of the formal theory on the introduction of special assumptions about the molecular forces, have not yet been obtained. It is our hope that these results, when found, may furnish an experimental test of the existence of Bose statistics in real gases, as is required by theory.

15. The equation of state of a non-ideal Einstein-Bose or Fermi-Dirac gas. G. E. UHLENBECK AND L. GROPPER, *University of Michigan.*—With regard to the question whether from isotherm measurements one can obtain an experimental test for the existence of Bose statistics in real gases, as is required by theory, we could prove the following general theorem. The "Zustandsumme" of a non-ideal Bose or Fermi gas is given by the classical integral provided one replaces the Boltzmann $exp(-V_{ij}/kT)$ factor by:

$$e^{-V_{ij}/kT}\left\{1 \pm \exp\left(-\frac{4\pi^2 mkT}{h^2} r_{ij}^2\right)\right\} \tag{1}$$

for each pair of molecules (i, j). For the second virial coefficient B, this has, i.e., in a Bose gas, as a consequence that:

$$B = B_{non\text{-}id.\ class} + B_{ideal,\ Bose} + B' \tag{2}$$

where:

$$B' = 2\pi N \int_0^\infty dr r^2 (1 - e^{-V/kT}) e^{-4\pi^2 mkT/h^2 r}\,. \tag{3}$$

Only at very low temperatures the last two terms in (2) become appreciable. They are then of the same order of magnitude, but have opposite signs. Due to this fact, due to the lack of precise knowledge of the molecular forces, and due to the absence of accurate measurements of B at very low temperatures, one can as yet not decide from isotherm measurements alone whether or not real gases obey the Bose statistics.

16. The theory of the atom of energy. E. K. PLYLER, *University of North Carolina.*—In the quantum theory of Planck it is postulated that energy is absorbed and radiated in definite amounts equal to $h\nu$. In the present theory it is postulated that there is a minimum of energy which may be emitted or absorbed and that all other amounts of energy are a multiple or this minimum. Whenever an electron absorbs energy its linear velocity will increase if no spin is produced. By the conservation of energy principle an equal amount of energy will be emitted when the electron is brought to its original velocity. In the case of the production of x-rays by the bombardment of a target with a stream of electrons, the collisions which decrease the velocity to zero at one time will produce the maximum or threshold frequency. Other types of collisions will cause the emission of smaller quanta of energy and these will make up the continuous spectrum which, is really a closely grouped discontinuous spectrum being made of various multiples of the atom of energy. More applications from optics and other branches of physics will be given and the more complete theory will be stated.

17. The Dirac electron in simple fields. MILTON S. PLESSET, *Yale University.*—The Dirac electron is considered first in one-dimensional fields in which the potential function $V(x)$ is a polynomial of any degree in x. By writing the equations of Dirac in a "canonical" form it is possible to attain an analytical symmetry which facilitates a detailed investigation of the behavior of the solutions at the singular points of the equations. It is found that there is no quantization in any of these cases taking the usual boundary condition of quadratic integrability. The particular case of the simple harmonic oscillator, $V = -ax^2$, is discussed in detail. For the oscillator in space, $V = -ar^2$, it is also found that there is no quantization. This treatment may be extended to show that Dirac's equations for any central field in which the potential function $V(r)$ is a polynomial in r give solutions with a continuous energy spectrum.

18. Calculation of first order atomic energies for configurations involving almost closed shells. GEORGE H. SHORTLEY, *Princeton University.*—A method is developed for calculating the electrostatic energy matrix for a configuration consisting of a closed shell minus ϵ electrons plus η other electrons with the same simplicity as for the corresponding configuration consisting of just $\epsilon+\eta$ electrons. One classifies the states according to the quantum numbers of the "missing" and of the added electrons and calculates Slater's integral $(J-\delta K)$ for each pair of electrons in the usual way except that one attaches a negative sign to an integral connecting a "missing" with an added electron. One obtains in general quite different formulas for the electrostatic energies for the two configurations mentioned above. This means, in the Russell-

Saunders case, that one obtains in general quite different multiplet separations and ordering of the multiplets. In the particular case $\eta=0$, however, one obtains the same formulas in the two cases, as has been shown by Heisenberg. It is then shown quite generally that the matrices of magnetic interaction are identical in LS coupling for the two configurations mentioned above except for a reversal of sign of the spin-orbit coupling parameter corresponding to the almost closed shell.

19. A rigorous treatment of assemblies containing crystals, in quantum and classical statistical mechanics. T. E. STERNE, *National Research Fellow, Harvard University and the Massachusetts Institute of Technology.*—The "Fowler-Darwin" method of finding the number C of linearly independent wave functions capable of representing an assembly with both crystalline and gaseous phases, of X similar systems and of total energy E, is to express C in the form of a double complex integral, and evaluate this by the method of steepest descents. Although the method of steepest descents when applied to this integral leads to the correct physical results, such use is not rigorous because the denominator of the integrand contains the expression $1-x\kappa(z)$ where x is a selector variable and $\kappa(z)$ is the crystalline partition function per system. A rigorous procedure is to find the number C_p of wave functions capable of representing the assembly of total energy E when there are P systems in the crystal, by the use of the method of steepest descents, in this case rigorous. To find C one then sums the resulting expression over all P less than X. The usual results of statistical mechanics follow directly. The method may be used for assemblies containing mixed crystals.

THURSDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

20. A graphical projection method of determining the coordinates of point-groups. DAN MCLACHLAN, *The Pennsylvania State College.* (*Introduced by Wheeler P. Davey.*)—The study of the 32 point-groups has so far required either that the student follow analytical methods blindly without visualizing the symmetry operations point by point, or that he follow, in imagination, the effect of rotating three-dimensional configurations of points about various axes. This paper describes a graphical scheme which enables a student to visualize the various symmetry operations by means of appropriate projections. For point-groups of cubic symmetry the whole cube is projected on its (111) plane, so that the cubic axes appear in projection as three equal lines spaced 120° apart. A template is made to the same scale, showing the projections of the three axes and showing, to the same projection, the coordinates of some point P. Mechanical manipulations of the template are described for showing the effects of various symmetry operations on the coordinates of P. Similar procedures are described for rhombohedral point-groups both with rhombohedral and with hexagonal axes. The use of triangular coordinate paper is described in making projections of hexagonal point-groups.

21. The principles of a new portable electrometer. ROSS GUNN, *Naval Research Laboratory, Washington, D. C.*—A new type of sensitive electrometer, sufficiently rugged for use on aircraft or shipboard and employing a standard portable microammeter for an indicator, is described. The instrument is a true electrometer and its leakage depends only on the amber insulation and the ionization of the surrounding air. The voltage sensitivity of a typical instrument is 10,000 microamperes (divisions) per volt. Sensitivities one hundred times this seem attainable after certain refinements in design are completed. The effective capacities of the instruments already built approximate 25 cm.

22. The x-ray scattering curves for NH_4 and I in NH_4I at various temperatures. G. A. MORTON, *Massachusetts Institute of Technology.* (*Introduced by B. E. Warren.*)—The f-curves for NH_4 and I have been determined for the two polymorphic forms of ammonium iodide for various temperatures. Measurements were made with an x-ray powder spectrometer using the

$K\alpha$ radiation of molybdenum. Intensity measurements were made on the high temperature form between +175°C and −50°C at intervals of 75°, and on the low temperature form at −20°C and −70°C. The form of the resulting f-curves is discussed and curves of the effective distribution of scattering matter in the crystal are given.

23. The shape of an x-ray line. ARCHER HOYT, *Cornell University.* (*Introduced by F. K. Richtmyer.*)—An x-ray emission line as measured by the double crystal spectrometer ("antiparallel" position) can be represented very accurately by means of a simple empirical formula of the type

$$y = \frac{a}{1 + (x/b)^2} \tag{1}$$

where the ordinate y represents the intensity $I(\lambda)$ as a function of $x \equiv (\lambda_0 - \lambda)$, *b the half-width at half-maximum*, a the maximum ordinate of the spectral line, and λ_0 the wave-length of that ordinate. Some uses for the formula are (1) location of background under the $K\alpha$ doublet, (2) the calculation of the separation of close components from measured points used in the empirical formula. Formula (1) appears to be a function of a very fundamental type since it is also a good representation of rocking curves obtained in the "parallel" position of the spectrometer. A search for theoretical justification of this type of formula has brought to light the curious result that although the application of the Dirac quantum theory of the radiation field yields a formula of the same type, the maximum ordinate predicted is independent of the spontaneous transition probability; whereas, certain experimental work indicates that the maximum ordinate is a good measure of the line intensity. This is very disturbing since the assumption is usually made that the line intensity *is* proportional to this Einstein coefficient of spontaneous transition.

24. Refraction of x-rays by calcite crystals. J. A. BEARDEN AND C. H. SHAW, *Johns Hopkins University.*—Previous measurements of the refraction of the molybdenum K series by calcite have given values of $\delta = 1 - \mu$ which are about 7 percent higher than the calculated values. The present measurements have been made using a 90 degree prism in which the refracting surface was polished optically flat and approximately parallel to the (100) plane. The prism edge was carefully prepared according to the method described in Phys. Rev. **39,** 1 (1932). However, the refracted lines were not as narrow as they should have been, which indicates that it is very difficult to obtain a "perfect" prism edge with calcite. Two experimental methods were used; in the first the x-rays struck the refracting surface externally and in the second internally. The theoretical values were calculated from the quantum theory of dispersion using the crystal wave-lengths. The results are shown in the following table:

Line	λ	Method	δ(exp.)10^6	δ(theory)10^6
Mo K_β	0.6314A	First	1.465	1.467
Mo K_α	0.7093	First	1.852	1.853
Mo K_β	0.6314	Second	1.448	1.467
Mo K_α	0.7093	Second	1.827	1.853
Cu K_β	1.389	First	7.07	7.14
Cu K_α	1.538	First	8.67	8.76

The experimental and theoretical values are thus in agreement within the experimental error.

25. The reflecting and resolving power of calcite for x-rays from 0.21 to 2.3A. SAMUEL K. ALLISON, *University of Chicago.*—Using a precision double crystal spectrometer, the rocking curves from three pairs of calcites in the (1, −1) position were observed for 7 wave-lengths from 0.21A (W $K\alpha$) to 2.3A (Cr $K\alpha$). Three quantities were observed at each wave-length, (1) the percent reflection ($\%R$), defined as the ratio of the maximum ionization current obtainable from crystal B to the ionization current produced by the x-rays incident on B from A, (2) the reflection coefficient (R), defined as the ratio of the area of the rocking curve from B to the intensity incident on B from A, (3) the half width at half maximum of the rocking curve from B. One of the pairs was obviously more perfect than the others. It is shown that none of the three quantities defined above is simply related to the analogous observations on a single crystal with monochromatic, parallel, incident x-rays, but that numerical predictions of the values of the above quantities may be obtained from somewhat laborious calculations based on Darwin's

theory of diffraction by a perfect crystal as modified by Prins to take account of absorption. At present a complete calculation has only been carried out for the reflection of Cr $K\alpha$. Results: $\%R$ predicted, 55.7; observed, 55.4: R pred., 4.25×10^{-5}; obs., 4.7×10^{-5}: half width pred., 7.4 seconds; obs., 7.1 sec. On the basis of this agreement it can be stated that it is possible to find specimens of calcite for which there is no evidence for a mosaic structure from intensity of reflection measurements.

26. Wave-lengths of the tungsten K-series spectrum with the double-crystal x-ray spectrometer. JOHN H. WILLIAMS, *National Research Fellow, University of Chicago.*—Using a Société Genevoise double-crystal x-ray spectrometer and the method devised by Compton (R. S. I. **2**, 365, (1931)), the K-series wave-lengths of tungsten were determined from the diffraction angles in the first order from calcite. The results, corrected for slit heights (Compton, Letter to the Editor, Phys. Rev., in press) and reduced to 18°C, are:

Line	Angle	Wave-length in X.U.
W $K\alpha_2$	2° 01′ 06.3″	213.37
W $K\alpha_1$	1° 58′ 22.3″	208.56
W $K\beta_3$	1° 44′ 51.4″	184.75
W $K\beta_1$	1° 44′ 24.8″	183.97
W $K\gamma$	1° 41′ 37.7″	179.06

The wave-lengths were calculated assuming the grating constant $d=3.02904$A at 18°C. The probable errors of the angle measurements are about $\pm0.2''$ except for $K\gamma$ and the random errors in the scale rulings of these instruments are approximately $\pm0.4''$. The separation of α_1, α_2 agrees exactly with the energy difference $L_{II}-L_{III}$. The β_1, β_3 lines were easily resolved in the first order and give a separation of 0.78 X.U. agreeing closely with the energy difference $M_{II}-M_{III}$.

27. Forbidden x-ray lines in the L series. S. KAUFMAN AND F. K. RICHTMYER, *Cornell University.*—On some of the long-exposure plates taken to bring out satellites, faint lines have been observed in the region of the $L\beta_2$ line of several heavier elements from $77Ir$ to $90Th$. These lines have been identified as diagram lines, forbidden by the usual x-ray selection rules and belonging to the two series $L_{22}-N_{21}$, $L_{22}-O_{21}$, $L_{22}-P_{21}$ and $L_{22}-N_{22}$, $L_{22}-O_{22}$, $L_{22}-P_{22}$. The first member of each series $L_{22}-M_{21}$ and $L_{22}-M_{22}$ has been found by Idei for several elements in the same atomic number range. Ross has recently reported "forbidden" lines in the K series. Search for other "forbidden" lines is being continued.

28. The production of the molybdenum Lα satellites by fluorescent absorption of silver Lα radiation. F. R. HIRSCH, JR. AND F. K. RICHTMYER, *Cornell University.*—The molybdenum $L\alpha$ satellites have been obtained by fluorescent absorption of silver $L\alpha$ radiation, by means of a special x-ray tube designed for use with a Siegbahn vacuum-spectrograph. An exposure of 40 hours, with the x-ray tube running at 20 kv. and 30 m.a. brought out satellites of easily observable intensity. A plate taken by cathode ray excitation, with the same intensity of molybdenum $L\alpha_1$, shows satellites of about the same intensity as in fluorescence. This is in disagreement with the results of Coster and Druyvesteyn who found the intensity of the satellites to be much less for fluorescent excitation, as compared with cathode ray excitation. Work is in progress to show whether the satellites on the fluorescent plate are due to true fluorescence or merely to the high speed photo-electrons ejected by high energy white radiation quanta, which are able to doubly ionize atoms in the molybdenum fluorescent anticathode.

29. Satellites near the Kβ_1 line. O. REX FORD AND C. B. POST, *West Virginia University.*—For the elements Sc(21), Ca(20) and K(19) the B-satellites are found to be more numerous than previous literature reports them. A satellite of shorter wave-length than $K\beta^{III}$ has been found in the elements K(19) to Sc(21). This satellite is given the name $K\beta^{IV}$. Another satellite, very close and on the short wave length side of $K\beta_1$ is found in the elements K(19) and Ca(20). The semi-Moseley diagram of these two new satellites has the same behavior as in the case of the other satellite lines. Experimental evidence is offered to show that all the B-satellites present a much greater regularity when referred to $K\alpha_2$ as the parent line instead of $K\beta_1$ as has been customary. If the B-satellites are related to the $K\alpha_2$ line rather than $K\beta_1$ a new classification of the K-satellites is demanded, in which there are no satellites on the long-wave-length side of the parent lines. The semi-Moseley diagrams are very valuable in the investigation of new elements.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

Paper No. 38 will be read by title.

30. Comparison of effects produced by 200 KV. x-rays. 700 KV. x-rays and gamma-rays. G. FAILLA, *Memorial Hospital, New York. (Summary of results obtained by different investigators at Memorial Hospital.)*—The influence of wave-length *per se* on the effects produced by ionizing radiations is being investigated intensively at the Memorial Hospital from different angles. The results reported at this time are based on the following effects: *Biological:* (1) reduction in linear growth of roots and shoots of wheat seedlings, (2) killing of fruit fly eggs, (3) reduction in linear growth of the tails of young mice, (4) epilation of a section of the tail, (5) severance of the end of the tail beyond the irradiated section, (6) epilation of the ears of rabbits, (7) erythema (reddening) of the human skin. *Chemical:* (8) precipitation of mercuric chloride from Eder's solution, (9) decomposition of potassium iodide in acid solution, (10) darkening of photographic film, with and without intensifying screens. *Physical:* (11) ionization in different ionization chambers. The results show that wave-length plays an important part in the degree of effect produced. From a practical standpoint the most important result is that human skin and other living tissues (all made up of low atomic number elements) do not react in the same way to the three qualities of radiation.

31. The reduction by x-rays of aqueous chromic acid solutions and the influence of added organic substances. HUGO FRICKE AND MARTHA WASHBURN. *The Walter B. James Laboratory for Biophysics, Cold Spring Harbor, L. I.*—A study has been made of the reduction of solutions of chromic acid in concentrations varying from N/500 to N/36000 chromate by irradiation with different dosages of x-rays. It is concluded that the effect is due to a primary activation of the water by the rays. Various organic substances increase the action of the rays, some having a marked effect in as low a concentration as 10^{-7} molar. The effect of the organic substance decreases in low concentration, according to a relationship which may be accounted for by assuming that organic molecules take part in the reaction when they encounter activated molecules which exist for a limited time only. The dependence of the effect on chemical composition forms an interesting subject which has been studied to some extent. For example, the effectiveness of the normal monobasic acids of the paraffin series increases rapidly with the length of the chain, valeric acid being over 100 times more active than acetic acid.

32. Further x-ray evidence as to the size of a gene; and as to the energy of mutation by ultraviolet rays. OSWALD BLACKWOOD, *The University of Pittsburgh.*—The author's previous minimum value, (130A), of the radius of the gene nucleus of the fruit fly is changed to 200A when x-ray bulb absorption is taken into account. In causing mutation by x-rays only one ion pair is produced if the radius is 130A and thirty if Muller's maximum value, (600A), is correct. The threshold frequency limit for ultraviolet capable of causing mutation probably lies below the window glass limit, 3150A. It certainly is above the shortest mercury arc line, 2480A. The corresponding energy excitation values of the gene are four and five electron volts. The spectral transmission of fruit fly larva "skins" has been determined by the author. With Altenberg's data the energy to cause mutation is determined. The value depends upon the assumption as to the threshold limit and is between 50 and 1800 times that for x-rays. The number of quants absorbed in the gene is between 300 and 10000. This low efficiency suggests that multiple excitations are necessary which progressively raise the energy to a value adequate for mutation.

33. Methods for computing lattice energy constants, R. H. CANFIELD, *Naval Research Laboratory, Anacostia, D. C.*—The classical methods of calculating lattice energies depend on the existence of special functions which limit the symmetry of the lattices to which they may be applied. The present paper describes two methods applicable to lattices of any symmetry. The first method, applied to the Coulomb potentials, involves the calculation of the potential of an ion at the center of an ever-enlarging sphere of crystal-lattice. At each step a special cor-

rection layer is added, such that the net charge of the whole sphere is zero and the volume integral of the potential energy is zero. This progression approaches a limit which may be determined to four digits by plotting. The second method is applied to potentials having exponents of $1/r$ higher than three. In this method the energy is computed exactly for a large sphere of surrounding atoms, and the remainder of the crystal to infinity replaced by a volume integral over a uniform distribution of matter. The lower limit of this integral is the boundary of a sphere containing matter equal to the actual content of the crystal sphere which furnishes the main term. This method gives results to six digits. Numerical results are given.

34. Molecular rotation in the solid state and the polymorphic relations of the univalent nitrates. F. C. KRACEK, TOM F. W. BARTH AND C. J. KSANDA. *Geophysical Laboratory, Carnegie Institution of Washington.*—The group of univalent nitrates affords a particularly important array of closely related structural types. The K, NH_4, Rb, Cs, Tl and Ag nitrates all exhibit polymorphism; crystallographic observations indicate that certain structural types may be common to two or more members of the series. Li and Na nitrates are not polymorphic, but $NaNO_3$ exhibits a gradual transition ending at 275°C which has been interpreted in terms of a gradual initiation of rotation of the nitrate group (J. Am. Chem. Soc. **53**, 3339 (1931)). In NH_4NO_3 the nitrate group rotation is initiated at a polymorphic inversion (Nature **128**, 410 (1931)). In some of the other members of the series the rotation of the nitrate group is likewise initiated at a polymorphic inversion. Thus, in KNO_3, the room temperature orthorhombic modification KNO_3(II) inverts to a holohedral trigonal form, KNO_3(I) at 127.7°C. The intensities of x-ray diffraction from KNO_3(I) ($a_0=4.50$A, $\alpha=73°\ 30'$, space group D_{3d}^5, $d=2.03$ calcd. with 1 KNO_3 per unit of structure, obsd. $d=2.03$) are explainable only on the assumption of the nitrate group being in motion about the trigonal axis. On cooling KNO_3(I) to below 125°C the salt inverts metastably to a pressure modification KNO_3(III) by a single crystal transformation. KNO_3(III) is ditrigonal pyramidal, space group C_{3V}^5, $a_0=4.37$A, $\alpha=76°\ 55'$, one KNO_3 per unit of structure, $d=2.13$ calcd., $d>2.10$ obsd. The NO_3 groups in this modification occupy fixed positions. Other examples will be considered.

35. The unit of structure of the minerals of the sodalite family. TOM F. W. BARTH. *Geophysical Laboratory, Carnegie Institution of Washington.* (*Introduced by F. C. Kracek*).—Minerals of this family are made up of the following three silicates (formulae for the full unit cells are given):

I. $Na_8Al_6Si_6O_{24}Cl_2$; II. $Na_8Al_6Si_6O_{24}SO_4$; III. $Ca_{4-5}Al_6Si_6O_{24}(SO_4)_{1-2}$.

I = sodalite, II = noselite, III is present in hauyne. An atomic arrangement for noselite in which two Na-atoms have no fixed positions in the lattice ("vagabonding ions") has been proposed by Jaeger. But this hypothesis is not in agreement with the known facts. The structure of sodalite as proposed by Pauling is correct, but does not explain the isomorphous relationship to silicates II and III. The following table shows, however, that the sodalite structure also can be described as belonging to space group T_d^1 (by applying the principle of variat atom equipoints) whereby the relationship to noselite and hauyne becomes evident.

	Space gr.	Na_8	Al_6 Si_6	O_{24}	Cl_2, S	O_4
Sodalite (Pauling)	T_d^4	8*a*	6*g* 6*f*	general	2*a*	
Sodalite (Barth)	T_d^1	4*a*+4*a*	12*f*	12*g*+12*g*	1*a*+1*b*	
Noselite { II	T_d^1	4*a*+4*a*	12*f*	12*g*+12*g*	1*a*	4*a*
Hauyne { III	T_d^1	4*a*[+$\frac{1}{4}$(4*a*)]	12*f*	12*g*+12*g*	1*a*(+1*b*)	4*a*(+4*a*)

The varying composition of ultramarines (which also belong to the sodalite family) is explained as a consequence of the variate atoms encountered in the position 12*f*.

36. New orientations forming in a crystal of Ag-Cu during precipitation. C. S. BARRETT AND H. F. KAISER, *Naval Research Laboratory, Washington, D. C.*—The orientation of individual grains of a solid solution of Cu in Ag (4 weight percent Cu) has been studied by x-rays before and after annealing, with surprising results. X-rays reflected from a single grain in the quenched homogeneous alloy give strong and well defined spots, but these spots completely disappear

after annealing treatments varying from 7 to 38 hours at 300°C. Before the original spots have vanished new reflections appear, weak and elongated. These occur at diffraction angles indicating reflection from the solid solution instead of the precipitate. These reflections are not destroyed by further annealing. Photograms of these reflections on a Davey-Wilson camera, when analyzed by stereographic projection, disclose a series of new orientations of fragments of the original crystal. The new orientations are related to the orientation of the original crystal by rotations covering the angular range 36° to 54° about each of the axes [100], [010] and [001] of the original matrix. There is a preference for rotations of approximately 42° and 48° about these axes corresponding to the fragmentation of a single crystal into crystallites with six differ ent orientations. No type of twinning previously observed in metals accounts for such an effect; it can be explained by twinning only by going to high index planes as twinning planes, such as those of the form {830}, {940} or one intermediate between these. Photomicrographs were taken of the different stages of the process, and although the grains ceased to have the appearance of a homogeneous solid solution, characteristic twinning structures did not appear, nor did the usual Widmanstatten structure.

37. X-ray study of the plastic working of Mg-alloys. L. G. MORELL AND J. D. HANAWALT, *The Dow Chemical Company, Midland Michigan.*—An x-ray study has been made of the structure of Mg-alloys fabricated at various temperatures. Different processes of working such as rolling, forging, or extruding result in characteristic fiber structures as seen by the x-ray photograms. These patterns are identified by comparing with computed patterns for the hexagonal system with axial ratio $c/a=1.62$. In this way it is found that a forged Mg-alloy possesses a [001] fiber axis lying in the direction of forging, while extruded Mg-alloys show a [210] fiber axis lying in the direction of extrusion. These results are understood in terms of the planes and direction of gliding in the micro crystals in polycrystalline Mg. The x-ray diagrams serve also to show the grain size and distortion of the micro crystals as a function of the temperature and the degree of working.

38. Molecular structure of ice and water. E. L. KINSEY AND O. L. SPONSLOR, *University of California at Los Angeles.*—A new lattice for ice, so far as the hydrogen positions are concerned is proposed, based on the oxygen positions given by Barnes. The units H^+ and $H_3{}^-O_2$ appear, the latter built with three hydrogens forming an equilateral triangle in a plane midway between the oxygens. Large polarization effects arise and reasons are given to show why a lattice in which they are produced is preferred to a coordination structure in which they are not. The lattice provides dihydrol as the polymer in ice and water, and qualitatively explains many of the substance's abnormalities. The model is used to calculate the oxygen-hydrogen angle θ in the $H_3{}^-O_2$ unit, for the unit within the lattice, and within dihydrol, regarded as isolated. Approximate calculations indicate $\theta=30°$ to within a few degrees for the unit in the lattice. The effect of the lattice on θ is small (several degrees) whereas, it acts to increase the polarization at an oxygen nearly three fold. Use is made of this to account for the stability of dihydrol in the crystal lattice.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Chemistry Building, Lecture Room

39. Lorentz double refraction in cubic crystals. F. SEITZ, *Princeton University.*—In 1878 Lorentz pointed out that the classical crystal optics is a first approximation which neglects variations in the electric intensity of the light wave over the lattice. He returned to the problem in 1921 and gave an incomplete theory and performed experiments showing that rock salt is not optically isotropic. In this paper the basis for an extension of the classical theory is given by writing

$$P_i = \alpha_{ij}E_j + \beta_{ijk}\frac{\partial E_j}{\partial x^k} + \gamma_{ijk}\frac{\partial^2 E_j}{\partial x^k \partial x^e}$$

for the electric moment in unit volume P_i due to the electric intensity, E_j. The tensor α corresponds to classical theory. Voigt (1905) shows essentially how β is responsible for optical activity of crystals. The tensor γ gives rise to double refraction in addition to that due to α, so that double refraction may occur even where crystal symmetry makes α isotropic. For the cubic system γ has three independent non-vanishing components. Double refraction is predicted for wave-fronts in all planes except the (100) and the (111) planes so that a cubic crystal has seven optical axes with regard to the Lorentz double refraction due to γ. More experimental data are needed before the predictions can be checked.

40. Quantum analogue of Lorentz broadening of spectral lines. HENRY MARGENAU, *Yale University.*—Recently the effect of interatomic perturbations upon the position and breadth of absorption lines has been calculated. The broadening thus computed agreed with the observed half width as to order of magnitude, but left room for the simultaneous existence of other causes. Hence the question as to the significance of "collision broadening" arises. Clearly, the classical mechanism of this phenomenon, as suggested by Lorentz, has become illusory. A Fourier analysis of the incident radiation, leading to Lorentz' formula, is also to be rejected. There is, however, a possible quantum analogue of this phenomenon. Suppose that the intensity of the incident light which is being absorbed by a given atom varies in its intensity so strongly that it may be regarded as intermittent. If this intermittence is due to the screening by other atoms its period may be smaller than the average life time of the excited state. In that case it is easy to show, by the usual perturbation methods, that the half width of the absorbed line, $\Delta\nu$, depends on the period of intermittence, t. The result, $\Delta\nu = .45/t$, is practically identical in form with Lorentz' formula, $\Delta\nu = .32/\tau$, τ being the mean time between two collisions.

41. Theory of inelastic collisions. E. C. G. STUECKELBERG, *Princeton University.*—A theory of inelastic collisions very similar to the one by London (recently published in the Zeitschr. f. Physik) has been developed. If only two stationary states of the two colliding systems are considered and if the nondiagonal interaction energy matrix elements depend on distance only, the problem reduces to two simultaneous differential equations. For a rather special case of this nondiagonal interaction energy the problem can be solved for all velocities. It is interesting to observe the deviation from the Born-Dirac Collision theory. In the case of exact resonance (i.e. if the kinetic energy before and after collision is the same) a general solution can be given within the region of validity of the Wentzel-Brillouin-Kramers approximation. The interesting feature is that with increasing interaction-energy we find an increase in transition probability. But after this probability reaches one it begins to oscillate between 0 and 1 in a way which depends on the exact nature of the interaction energy.

42. Double Stern-Gerlach experiment and related collision phenomena. N. ROSEN AND C. ZENER (*National Research Fellow*), *Mass. Inst. of Tech. and Princeton University.*—The experiment of Phipps and Stern on the behavior of atoms in a rotating magnetic field led to results at variance with the theoretical predictions of Güttinger. A possible explanation is that the latter's calculations involved an abrupt change in the rate of rotation of the field that certainly was not present in the experiment. To mend this, the rate of rotation is represented by a continuous smooth function having a maximum at $t=0$ and going to zero at $t=\pm\infty$. An exact solution of the problem for a function of this type is obtained and it is found that the expression for the fraction of electrons that have reversed their spins with respect to the field at the end of the rotation is considerably different from Güttinger's and in complete agreement with the experiment of Phipps and Stern. The same analysis may be generalised to all classes of collision phenomena in which only two quantum states need be considered, and in which the difference in eigenwert of these two states, ΔE, is small in comparison to the relative translational energy. If $f(t)$ is the matrix element, with respect to the two states, of the perturbation, and $A = 2\pi/h \int_{-\infty}^{\infty} f(t)dt$, then the transition probability is given by

$$\left(\frac{\sin A}{A}\right)^2 \cdot \left| \int_{-\infty}^{\infty} \frac{2\pi}{h} t(t) e^{2\pi i/h \Delta E t} \right|^2.$$

43. The exchange of energy between monatomic gases and solid surfaces. CLARENCE ZENER, (*National Research Fellow*), *Princeton University.*—The calculation of the accommodation coefficient, α, of an inert gas with a metallic surface is intrinsically much simpler in the

quantum mechanics than in the classical mechanics. This simplification has been taken advantage of to find α as a function of the physical characteristics of the metal and gas. The dependence of α upon temperature is given primarily by the factor $(U-U_0)/T$, where U is the internal energy of the crystal. This is in agreement with the experiments of Richards on He and W. Two arbitrary parameters have been introduced, one the force constant d in the repulsive potential $V=Ce^{-r/d}$, the other a factor arising in averaging over all angles of incidence. These parameters will, however, be nearly constant for the series He, Ne, A. It is predicted that α will increase, remain constant, or decrease with the series He, Ne, A according as d is less than, equal to, or greater than 10^{-9} cm. Experiments are being carried out at Princeton to determine this force constant.

44. A critique of sp^3 valency. J. H. VAN VLECK, *University of Wisconsin.*—In the April 1932 Phys. Rev., Mulliken shows that by extending to polyatomic molecules the diatomic configuration theory of Mulliken and Hund, it is possible to form a model for valences in complicated molecules apparently without merging the s and p wave functions to yield the so-called sp^3 valences of Slater and Pauling. To study this question further, the secular determinant for CH_4 is now examined. It is found that the sp^3 hybridization is encountered only when the repulsions between the four electrons of the H atoms are included, and the Slater-Pauling form is a good aproximation only when these repulsions are fairly large. The Mulliken model, without the sp^3 combinations, allows four electrons to "pile up" sometimes on one H atom, just as the Hund two-center model in H_2 allows two electrons sometimes to be on the same H atom. Any attempt to predict tetrahedral properties from the geometry of the sp^3 wave functions without invoking electron repulsions appears somewhat questionable.

45. Multiplet splitting and intensities of intercombination lines. HUGH C. WOLFE, *Fellow of the Lorentz Foundation, University of Utrecht.*—Weyl has shown that many properties of free atoms can be derived on the basis of irreducible representations of rotations in R_3. Kramers has obtained an elegant formulation of Weyl's methods through the use of symbolic representation (theory of invariants) of wave functions and operators. This method is particularly adapted to the problem of multiplets (interactions between two or more "vectors," e.g. orbital angular momenta, spins). Integrations yielding matrix elements are only symbolic and the results, being determined by invariance properties, contain therefore unknown constant factors of the nature of radial integrals. Kramers' method is applied to spectra involving two valence electrons, of which one is in an s state, (singlet and triplet P, D, F, etc.). The constants which represent the interaction energies (1) electrostatic, (2) spin-orbit, (3) spin of one electron-orbit of the other (other types of interaction as yet being neglected) are expressed in terms of the three intervals of the singlet-triplet multiplet. These constants have been determined for many spectra. (3) is most often not negligible. The intensities of singlet-triplet intercombination lines are found in terms of the intervals and compared with observations on Hg.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

46. A method for sensitizing photographic plates to the short ultra-violet wave lengths. A. J. ALLEN AND R. FRANKLIN, *Cancer Research Fund, Graduate School of Medicine, University of Pennsylvania and The Bartol Research Foundation.*—As is well known, the sensitivity of ordinary photographic plates can be increased to wave lengths below 2400A by coating them with certain fluorescent mineral oils. The desirable oil converts the shorter waves into longer ones which are not absorbed by the gelatin. Oiling the plates, however, has certain disadvantages and uncertainties. The same principle is made use of in the following method of sensitization. Plates of the desired quality, i.e., size of grain and sensitivity, are submersed in a solution of 2½ g. amino G acid (Eastman Kodak Co. T. 477), 2½ g. sodium carbonate in 100 c.c. of water for a few seconds, the entire surface being lightly rubbed with a piece of absorbent cotton to insure

a uniform coating. They are then removed and allowed to dry in a vertical position on an ordinary plate drying rack. The result is a thin, rather durable coat of amino G salt crystals which give a bright blue fluorescence when exposed to ultra-violet radiations (also to x-rays and β and γ rays). A similar coating of Ga salt produces a greenish blue fluorescence which is not as effective as a sensitizer. After exposure, and just before developing and fixing in the usual manner, dip the plates in a pan of water, or rinse under the water tap for an instant to insure uniform development. Plates sensitized in this manner are compared with oil sensitized, Eastman ultra-violet sensitized, and plates sensitized with Eastman ultra-violet sensitizing solution.

47. A broad range vacuum spectrograph for the extreme ultra-violet. K. T. COMPTON AND J. C. BOYCE, *Massachusetts Institute of Technology.*—A two-meter focus normal incidence vacuum spectrograph has been constructed to cover with a dispersion of 4.3 A per mm. the whole range from the central image up to the first order of $\lambda 2500$. The body of the spectrograph consists of brass plates screwed and soldered together, the whole exterior being coated with glyptal lacquer. End covers, removable to permit introduction of the photographic plate and the adjustment of the grating, are each attached with two rubber gaskets. An auxiliary pumping system produces a rough vacuum between gaskets and prevents leakage past the inner ones. A Gaede mercury vapor pump with suitable liquid air trap provides an initial vacuum of about 10^{-5} mm. and then maintains in the spectrograph a pressure about one hundredth of that in the discharge tube used as light source. Hilger Schumann plates, 3 by 24 inches, on special thin glass are bent to the focal curve of the grating. A magnetic control provides for moving the plate between successive exposures. Preliminary tests with electrodeless discharge, capillary discharge, and hollow cathode lamp indicate that the instrument is suitable for the investigation of short wave-length spectra from gas discharges. Construction of this spectrograph was made possible by a grant from the Carnegie Institution of Washington.

48. Diffraction experiments with especial reference to the nature of errors of gratings. R. W. WOOD, *Johns Hopkins University.*—During the past two or three years a study had been made of the causes producing the very troublesome, though very faint, spurious lines which appear near the main lines in the case of practically all large gratings. They lie usually much closer to the main line than the first order ghost, and give an appearance of hyperfine structure. Visual and photographic records of the appearance of the grating surface as observed by the light of the spurious lines, (the main line and all but one spurious line being screened off by knife edges) show that narrow vertical elements of the grating conspire in the production of each spurious line. The cause of these non periodic errors of spacing is, without doubt, the variable friction which the grating carrier experiences as it moves along the ways of the ruling engine. Methods of reducing this trouble will be described, and photographs of various mercury lines made with the 40 foot spectrograph since its transfer to Tuxedo will be shown.

49. Quantitative spectrographic analysis. O. S. DUFFENDACK AND R. A. WOLFE, *University of Michigan.*—A method of quantitative spectrographic analysis based upon the relative intensities of selected spectra lines in a single spectrogram has been developed and shown to give as consistent results as quantitative chemical analysis. By determining the relative intensities of a selected pair of lines in a graduated series of specimens like the material under investigation, a working curve can be determined giving the relationship between the relative intensities of the lines and the percentage of the test element. This curve need be determined but once for analyses over a given percentage range. Hansen's step diaphram method of measuring relative intensities of spectral lines is used. When the test material is an alloy, an arc source is preferred. Investigation revealed that at certain arc currents, the relative intensity of the selected lines varies only slightly with the current. An arc of this current is used for the analysis. A theory of the intensities of spectral lines in an open arc has been developed and accounts for the relations used in the method. This investigation was made possible by support from the A. C. Spark Plug Company.

50. The structure of the ultra-violet absorption spectrum of formaldehyde. G. H. DIEKE, *Johns Hopkins University and G. B. Kistiakowsky, Harvard University.*—The ultra-violet absorption bands of CH_2O were photographed in the third order of the 40 foot Tuxedo spectro-

graph, and until now the bands at 3520, 3430 and 3390 A analyzed. Their structure is, both as far as the position and the intensities of the lines are concerned, exactly what has to be expected theoretically for a molecule of this type. The molecule is almost a symmetrical top. The deviations from this shape are felt only for $K<4$, and result in a doubling of the lines which increases with increasing J. Lines belonging to successive rotations about the CO-axis show intensity alternations as in the hydrogen molecule. The expected combination relations are fulfilled within the limits of experimental errors. The three moments of inertia for the ground level are $A=24.58$, $B=21.63$, and $C=2.951\times10^{-40}$ This gives for the H−H distance 1.88 A, and if the angle between the CH bonds is assumed to be the tetrahedron angle, for the C–O distance 1.19 and for the C–H distance 1.15A. Henry and Schou's previous analysis was not confirmed.

51. A new system of bands in sulphur dioxide. T. C. CHOW, *Princeton University.*—About eighty bands in the region 2000–2400 A.U. were recorded from a discharge in sulphur dioxide gas flowing rapidly. No trace of sulphur could be detected in the tube after nine hours exposure. Two thirds of these bands have been arranged in a scheme of levels. Comparisons with the known band spectra of SO, O_2, and O_2^+ show quite definitely that these bands do not belong to any of these known systems. Particularly the known system of bands of SO (2400–3940 A.U.) has many different features from these bands. Because of the weakness of the source, rotational structures have not been obtained. It appears that these emission bands may be due to the SO_2 molecule itself. Absorption measurements in SO_2 were therefore undertaken. (In the region 2400–2000 A.U. no accurate measurements have ever been published.) About sixty strong absorption bands were recorded and arranged into sequences. Twenty bands which constitute three sequences appear both in emission and absorption. This agreement between absorption and emission gives quite a strong support to the hypothesis that SO_2 is the probable emitter of those emission bands.

52. The near infra-red bands of ammonia under high dispersion. J. D. HARDY, *National Research Fellow, University of Michigan.*—The Ammonia bands at 1.5μ, 1.9μ, and 2.2μ have been studied under high dispersion and the fine structure of the first and last of the two bands has been brought out for the first time. From theoretical considerations, supported by the complex character of the band, the 1.5μ band is attributed to the overlapping of several combination bands. The band at 2.2μ is of the perpendicular type as is the band at 1.9μ. Barker, who first resolved the $1.9\ \mu$ band, suggested that it might be a fundamental but a further study of this band and the one at 2.2μ seems to indicate that this classification might be wrong. Further investigation of the molecule in the light of present data will be needed to throw light on the perpendicular type of vibration.

53. Vibrational levels in ammonia-like molecules. PHILIP M. MORSE AND N. ROSEN, *Massachusetts Institute of Technology.*—Dennison has shown that the nitrogen atom in the ammonia molecule can vibrate along a line perpendicular to the plane of the hydrogen atoms, and that it has two symmetrically placed points of equilibrium. The nitrogen atom's potential field thus has two minima, separated by a "hill." Quantum mechanics requires that the vibrational levels for such a field be doublets, which has been observed in the ammonia spectrum. The writers have found a form of potential field whose levels could be computed with good accuracy, giving values of the levels and the doublet separations in good agreement with the experimental data of Dennison and Hardy. This field has its two minima 0.73 Angstroms apart, separated by a "hill" 1/4 volt high.

54. Predissociation in the spectrum of iodine chloride. WELDON G. BROWN, *National Research Fellow, University of Chicago* AND G. E. GIBSON, *University of California.*—A group of bands lying just beyond the convergence of the ordinary visible absorption bands of iodine chloride have been analyzed and found to consist of *P* and *R* branches. The upper state for this system is derived from normal iodine and excited chlorine atoms and is interpreted as the $^3\pi_{0+}$ state predicted by Mulliken. It is thus analogous to the upper states of the well-known visible bands of the homonuclear halogens. The upper state of the ordinary ICl bands is now known to dissociate into two normal atoms and is classified as the $^3\pi_1$ member of this multiplet. Above the level $v=3$ of the $^3\pi_0$ state predissociation sets in, presumably as a result of interaction with a

repulsive O^+ state derived from two normal atoms. Apparently the intersection of these curves gives rise to a new state with a minimum at the point of intersection, for at this point a new set of energy levels is observed to begin. In absorption transitions to this state result in sharp lines only if the energy levels coincide at the same rotational quantum number with the levels of the original $^3\pi_0$ state. Otherwise the lines are diffuse. This is interpreted as due to momentary existence of the molecule in the $^3\pi_0$ state as an intermediate step in the absorption process, a step which is followed either by predissociation giving normal atoms or by a radiationless transition into the new O^+ state.

55. Infra-red spectra of the noble gases. WILLIAM F. MEGGERS AND C. J. HUMPHREYS, *Bureau of Standards.*—The first spectra of He, Ne, A, Kr and Xe have been photographed with complete details from 7600 to 12100A by exploiting two very remarkable emulsions made by the Eastman Kodak Company. These plates have sensitivity maxima at 8600A and at 9600A. The first plate was used for the range 7600–9200A and the second for 8600–12100A. The sources were Geissler tubes operated with uncondensed high voltage a.c. discharges, and the spectrographs were concave gratings of 21 feet radius except for the last 900A which were observed with a Hilger E_2 spectrograph with glass prism. Many new lines have thus been added to the spectroscopic data for each of the noble gases and analysis has resulted in confirmation and extension of the tables of spectral terms. A new band extending from 9100 to 11000A has been observed in He. The resonance lines of He have been measured as 10829.09 (20) and 10830.30 (100). The longest wave lengths recorded in Ne, A, Kr and Xe are 12066, 11738, 12124, 11134A, respectively. The second spectra are being investigated in the infra-red in the same manner.

FRIDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

56. An extension of the Pd I-like isoelectronic sequence to Sb VI and Te VII. G. K. SCHOEPFLE, *Cornell University.* (*Introduced by J. R. Collins.*)—Terms arising from the configuration d^{10}, d^9s, d^9p of Sb VI and Te VII are given along with the wave-lengths and frequencies of the stronger lines. Term separations and a Moseley Diagram are given and the centroids are computed for the entire sequence. The lines for the transitions $^3P\ D\ F$, $^1P\ D\ F$ ($4d^95p$) into ^3D, ^1D ($4d^95s$) fall in the vacuum region between 784A and 1331A, while for the shorter wave length lines for the transitions $^1P_1$, $^3P_1$, and $^3D_1{}^0$ ($4d^95p$) into $^1S_0(4d^{10})$, the frequencies are obtained by extrapolation of the Moseley Diagram.

57. Hyperfine structure of Ga II and In II. J. S. CAMPBELL, *National Research Fellow, University of Chicago.*—The spectra of ionized gallium and indium, photographed with a 21-foot grating, show wide hyperfine structure. The assumption of $i=3/2$ for gallium best fits the observed separations and estimated intensities; a nuclear moment of at least 5/2 is indicated for indium. Relative separations of a number of terms agree with the formula of Goudsmit and Bacher (Phys. Rev. **34**, 1501 (1929)) for two-electron configurations involving an s electron. The In I lines classified by Sawyer and Lang (Phys. Rev. **34**, 712 (1929)) as $(4s^24p)\ ^2P-(4s\,4p^2)\ ^4P$ show hyperfine structure which is due to the quartet term, and which substantiates their classification.

58. A test of hyperfine structure theory. R. F. BACHER, *Mass. Inst. of Tech.* AND J. S. CAMPBELL, *University of Chicago, National Research Fellows.*—The total hyperfine structure separations of the two members of the doublet arising from the single $5p$ electron have been found from a study of the resonance lines of indium. The values of these separations represent averages of observations with a variety of plate separations with a Fabry-Perot interferometer. Difficulties due to isotope displacement and the corresponding complication of the patterns are not found in indium as it is a single element. Since it may be shown that the nuclear moment of indium is greater than $1\frac{1}{2}$, the theoretical value as given by Fermi or Racah for the ratio of these separations is independent of the nuclear moment. $\Delta^2P_{\frac{1}{2}}$ is found to be 0.390 cm.$^{-1}$ and $\Delta^2P_{1\frac{1}{2}}$ to

be 0.133 cm.$^{-1}$ giving a ratio 2.9. This is not in agreement with the uncorrected theoretical value 1.67; it is in somewhat better agreement with the value corrected according to Racah, 2.05; and it is in quite reasonable agreement with the value corrected according to Breit, $\backsim$2.7.

59. Hyperfine structure of the vanadiam spectrum. H. E. WHITE, *University of California, Berkeley.*—Our present knowledge concerning the hyperfine structure of spectral lines enables one to predict for vanadium (at. wt. 51, at. no. 23), a finite nuclear spin and a hyperfine structure. Because of the hundreds of lines in the vanadium arc spectrum and the high intensity required for interferometers only a few of the lines are sufficiently isolated for study. The V I lines were excited in an atmosphere of argon by means of a Paschen hollow cathode cooled to liqud air temperatures (a Schuler tube). With a large three prism glass spectrograph in conjunction with Fabry-Perot Etalons a number of the lines have been observed as narrow unresolved hyperfine multiplets. Eight or ten of the wider patterns (total width about 0.1A) have been studied in an effort to determine the nuclear spin. In the quartet system of multiplets, λ4851 ($^4D_{1\frac{1}{2}} - {}^4F_{2\frac{1}{2}}$) reveals four diagonal components. λλ4670 ($^4P_{2\frac{1}{2}} - {}^4D_{3\frac{1}{2}}$) and 5670 ($^4D_{3\frac{1}{2}} - {}^4F_{4\frac{1}{2}}$), although not completely resolved, appear to contain six components. The first three or four diagonal components of these lines are resolved and the remainder of the pattern indicates two more making six in all. With these preliminary results one can say that for the vanadium nucleus $I \geq 5/2$, and that the g-factor is small. The total widths of the unresolved patterns for the multiplet $^6D - {}^6F$ ($3d^4 4s - 3d^4 4p$) are in excellent agreement with Goudsmit's equations.

60. The Paschen-Bach effect of hyperfine structure and the polarization of resonance radiation: the D lines. L. LARRICK, *State University of Iowa.*—The polarization of sodium resonance radiation has been calculated on the basis of the hyperfine multiplet theory of Goudsmit and Bacher as a function of the hyperfine separation constants of the $1^2S_{1/2}$ and $2^2P_{3/2}$ levels and the intensity of an applied magnetic field for a nuclear moment of one (in units of $h/2\pi$). Comparison with experiment shows good agreement with A = .0012 cm^{-1} for the $2^2P_{3/2}$ level, except for very small fields (H = 40 gausses) in which the polarization increases less rapidly than the theory demands. This is probably due to the fact that the first approximation used takes no account of the finite breadth of levels.

61. Polarization of sodium resonance radiation and nuclear moment of the sodium atom. N. P. HEYDENBURG, L. LARRICK, AND A. ELLETT, *State University of Iowa.*—The polarization in zero magnetic field of sodium D line resonance radiation is calculated as a function of the nuclear moment I. For plane polarized exciting radiation (D_2 alone) we find

$$P_{D_2} = \frac{16I^6 + 48I^5 + 64I^4 + 48I^3 - 5I^2 - 31I - 18}{112I^6 + 336I^5 + 288I^4 + 16I^3 - 73I^2 - 17I - 6}$$

$$P_{D_1} = 0.$$

From this we calculate the table below:

I	P_{D2}	P_{D2+D1}
0	60	50
1/2	40.54	33.33
1	20.50	16.6
3/2	18.61	15.07
2	17.33	14.02
5/2	16.47	13.32
3	15.91	12.84
7/2	15.54	12.56
4	15.28	12.35
9/2	15.09	12.19
	14.28	11.54
Observed		16.48 ± .33

The polarization was measured by the Cornu method—observations made by four observers showed good agreement giving a mean value of 16.48 ± .33 per cent. This agrees well with the result calculated for $I = 1$ whereas observations on band spectra indicate $I \geq 3/2$ and present ideas of nuclear structure demand I = odd multiple of $\frac{1}{2}(h/2\pi)$.

62. Quenching of mercury resonance radiation by H_2, CO, and N_2. J. S. OWENS AND O. S. DUFFENDACK, *University of Michigan.*—The quenching of mercury resonance radiation by H_2, CO, and N_2, at temperatures from 200°C to 700°C, has been investigated with a two-fold purpose: (1) the determination of the dependence of the quenching upon the temperature, and (2) the determination of the reactions occurring in the quenching process by each gas. Accurate quantitative measurements of the quenching were made possible by improved equipment and technique. Quenching by H_2 was found to be independent of the temperature, and to consist of a two-step process; hence action radii of 2^3P_1 Hg atoms calculated upon the basis of a one-step process have little actual meaning. Quenching by CO and by N_2 was found to decrease with increase in temperature, and the process of quenching to be very complicated. Equations were derived which fit the experimental curves within experimental error (2% for H_2 and CO, 5% for N_2). For CO and N_2 the processes occurring were determined, but not their individual probabilities. In the case of H_2, the probability of each process of the reaction was evaluated.

63. Collisions of the second kind involving ionization and excitation. K. B. THOMSON AND O. S. DUFFENDACK, *University of Michigan.*—A study has been made of the excitation of spark levels in metallic atoms by collisions of the second kind with rare gas ions, as a function of the energy discrepancy. The enhancement of the relative populations of certain levels, with respect to their populations in a "normal" discharge was measured by comparing the relative intensities of lines originating in these levels in the two types of excitation. The relative intensities were measured by a modification of Hansen's step-diaphragm method. A small diaphragm was made, for which the ratio of the widths of successive steps was 1.5. There were 6 steps in all, and the widest was 3 mm. Intensity markers were placed on the plates by replacing the slit of the spectrograph with this diaphragm and photographing the continuous spectrum from a condensed aluminium or magnesium spark in hydrogen. The results show that, while in general the probability of excitation of a level increases as the discrepancy between the level (measured from the normal atom) and the ionization potential of the rare gas atom decreases, there are exceptions to this rule. In certain cases, where a triplet level and a singlet level had about the same discrepancy, the triplet level was distinctly preferred. Anomalous results were also obtained for the $d^9\,6s$ levels of silver.

64. Electron temperatures and the concentration of excited atoms in a caesium positive column. F. L. MOHLER, *Bureau of Standards.*—Probe measurements in the positive column of a caesium discharge give the electron energy, electron concentration, the power input per cm, and the power loss by flow of ions to the walls. The power input under low pressure low current conditions must be largely accounted for by inelastic collisions at the first resonance potential and the measurements give a value of the effective collision area of about 5×10^{-15} cm². With high currents and pressures the power loss by inelastic collision would be many times the power input except for the fact that collisions of the second kind give back the excitation energy to the electrons. The concentration of excited atoms must then be nearly equal to the equilibrium concentration for a temperature equal to the electron temperature. This conclusion has been checked by photographing the spectrum of a strip lamp as viewed through the discharge tube and finding the lamp temperature at which the resonance lines disappear. The lamp temperatures are in general slightly less than the electron temperatures though the difference is scarcely more than the experimental error. This shows that there is nearly an equilibrium between the electrons and the first excited state.

65. The angular distribution of electrons scattered elastically and inelastically in mercury vapor. JOHN T. TATE AND R. RONALD PALMER, *University of Minnesota.*—A long electron gun was mounted to rotate about a well shielded scattering region from which electrons scattered by gas molecules through a definite angle from a beam of small cross-section were collected, and their velocities determined, by a stationary collector containing an efficient Faraday cage, 6.0 cm in length. Angular distribution curves for electrons scattered elastically, for electrons scattered at excitation of the atom (mainly 6.7 volt energy loss), and for electrons resulting from ionizing impacts are presented for 80, 120, 230, 490, and 700 volt electrons. In general, for a particular group the curves are steeper the higher the velocity of the incident electrons. The curves for the elastic group show a diffraction at large angles, and the positions of the peaks

agree well with those found by Arnot. The curves for the excitation group are much steeper than are those for the elastic group, and fall to very small values at large angles. The curves for the ionization group are also steeper but not so steep as the excitation group. The ionization group is divided into sections and further characteristics are observed. Numerical integration of these curves gives the cross-sectional area for collision, the efficiency of ionization, and the efficiency of excitation for electron impact.

66. Polarization of radiation from metals bombarded by slow electrons. C. BOECKNER, *Bureau of Standards.*—A metal electrode in a gas discharge (Cs vapor) when drawing large electron currents has been found to emit radiation having a continuous spectrum throughout the visible and ultra-violet. Since the direction of motion of the bombarding electrons is normal to the surface, one might expect from analogy to continuous x-rays that the radiation should be more intense for oblique angles of emission and should be partially polarized. This was found to be the case for both tungsten and platinum. Light polarized with the electric vector in the plane of emission is about three times more intense when observed at 60° to the normal than when observed in a direction normal to the electrode surface. The intensity with the electric vector perpendicular to the plane of emission was approximately independent of the angle of emission. From measurements made on electrodes heated to incandescence it was found that the intensity of the thermal radiation varied only slowly with angle for both directions of polarization. This latter fact renders it difficult to explain the intensity relations by considerations involving the optical properties of the metal.

FRIDAY MORNING AT 10:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

67. Influence of the electrical discharge on the secondary emission from the cathode. WILFRID J. JACKSON, *New Jersey College for Women, Rutgers University, New Brunswick, New Jersey.*—Measurements have been made, using the same apparatus as described by Jackson, (Phys. Rev. **30,** 473 (1927)), on the secondary emission from a molybdenum cathode as influenced by the electrical discharge in hydrogen at low pressure. The secondary emission from the Mo target, which had not been heat treated, increased from about 1% at 250 volts to 14% at 750 volts when bombarded by K^+ ions, and showed a marked decrease after a discharge in hydrogen had been passed for 5 minutes using the Mo target as cathode. In the latter case the emission could not be detected for positive ion velocities less than 400 volts and reached a value of about 4% at 750 volts. The gas was pumped out and the pressure reduced to about 10^{-5} mm. of mercury in all cases before measurements were taken. The general aspects of these results are in agreement with results published by Câmpan, (Physik. Zeit. **23,** 593 (1931)). Work is in progress using other targets and gases.

68. Measurement and observation of vacuum conditions in finished (sealed-off) vacuum tubes, incandescent lamps and gas discharge devices. HENRY J. MILLER, *Emporium, Pa.*—Direct current and alternating current measuring methods employing audio and radio frequencies are described which are used to determine the degree of vacuum as well as to study the changes of vacuum occurring in sealed off vacuum and gas filled electrical devices. An attempt is made to show that the type of exhaust and the kind of getter employed to produce the vacuum has a definite influence upon the vacuum characteristics as determined by the methods which are described. Special reference is made to the use of the abnormal shot effect for the purpose of determining vacuum conditions in radio receiving tubes.

69. Effect of a glass target on cold emission. WILLARD H. BENNETT, *Mendenhall Laboratory of Physics, Ohio State University.*—Using the method described previously, (Phys. Rev. **39,** 182 (1932)) emission from a cold cathode was directed at a glass disk in a magnetic field. Behavior of the emission shows that a stream of positives from the glass target follows the electron stream back to the cathode. This stream of positives persists indefinitely and the spot on

the glass where the electrons strike deteriorates slowly. The observation regarding the abundance of this supply of positives and its effect on the severity of breakdown confirms the theory of breakdown offered previously. It further shows that in the design of high voltage tubes, it is not sufficient to degas the electrodes but one must give careful consideration to the effect of the possible targets of small emission currents on possible breakdown. A tube intended to be used in investigations on atomic disintegrations is to be built at this laboratory using the principles arrived at in the work on cold emission.

70. The disappearance of gas in discharge tubes. ALBERT W. HULL AND E. E. BURGER, *General Electric Co., Schenectady, N. Y.*—These experiments were undertaken to test the hypothesis, for which there was experimental evidence, that the disappearance of noble gases in an electric discharge is due to penetration of the ions into the cathode surface, whence they diffuse very slowly. An arc plasma was drawn into the annular space between well de-gassed metal cylinders, one of which was charged to negative voltages up to 1000. The rate of disappearance of gas, at constant pressure and voltage, was found to decrease as the total amount absorbed increased, indicating saturation. Nearly all of this gas could be recovered by heating the cathode, which also restored the initial rate of cleanup. The following evidence, however, indicates that part of the cleanup is of a different nature: 1st. The greater the amount cleaned up, the smaller is the fraction that can be recovered. 2nd. When the two cylinders are heated separately, it is found that the external cylinder, which received the sputtered deposit, also contains absorbed gas, in general more than the negatively charged cylinder. It is concluded that gas disappears both by penetration into the cathode and by adsorption on the sputtered deposit.

71. Measurements of small currents using pliotron tubes. L. R. HAFSTAD, *Johns Hopkins University and Department of Terrestrial Magnetism, Carnegie Institution of Washington. (Introduced by J. A. Bearden.)*—The sensitivity of the single-tube circuit using the FP-54 Pliotron was considerably increased by mounting the tube in a vacuum, keeping the batteries at constant temperature and, following Professor Ruark, operating the tube with the floating control grid initially at its equilibrium potential. The limiting fluctuations apparently inherent in the tube itself were determined by using extreme precautions with the batteries and accessory apparatus and were reported at the Cambridge meeting. For the photographic recording of alpha- and hydrogen-particles over long periods of time only moderate sensitivities are required but the steady drift must be made small. A completely new set was assembled for the above purpose in which drifts of less than 10 mm per hour were obtained by means of a loaded counter-cell. With ordinary precautions and with low film speed (20 centimeters per hour) a sensitivity of 400 electrons per millimeter shows small fluctuations of about 2 mm in 30 seconds. Slow deviations as large as 8 mm in three minutes also appear but these cannot be confused with pulses such as are produced by particles when the ionization-chamber is connected. This represents a practical sensitivity which is directly attainable.

72. Evaporation and migration of thorium on tungsten. WALTER H. BRATTAIN, *Bell Telephone Laboratories, Inc.*—The work reported in abstract (Phys. Rev. **35,** 1431 (1930)), was continued. Thorium evaporates from a tungsten surface at an appreciable rate at 2200°K. The evaporation rate depends on the temperature and the fraction of the surface covered (f). Except for small values of $f<.2$ the rate of evaporation is approximately an exponential function of f. The rates of evaporation determined by Langmuir, (Phys. Rev. **22,** 357 (1923)) and Andrews, (Phys. Rev. **33,** 454 (1929)), are comparable with the above results when account is taken of the difference between Langmuir's parameter θ and our f. It was found that thorium could be deposited on one side of a tungsten ribbon and then made to migrate to the other side by flashing the tungsten ribbon at 1535°K. to 1655°K. This could be done without loss of thorium due to evaporation. The thorium lost from the front side Δf_1 was always equal to the amount gained by the back Δf_2. This constitutes a proof that f is proportional to the amount on the surface. The rates of migration were determined at 1535°K. and 1655°K. They depend on the difference in concentration (f_1-f_2) in much the same way as the rate of evaporation depends on f.

73. The emission of positive ions from heated metals. LEROY L. BARNES, *Cornell University.*—Filaments of iron and nickel have been heated in a mass spectrograph, and at temperatures just below their melting points it is found that singly charged atoms of iron and nickel are

emitted. Similar attempts to obtain positive ions of platinum, uranium and thorium have not met with success. Rhodium and columbium ions have been obtained, which is in agreement with the results already reported by H. B. Wahlin.

74. On thermionic currents limited by pure electron space charge. EVERETT W. THATCHER, *Union College, Schenectady, N. Y.*—Work has been continued on the damping of thermionic emission variations with increasing space charge (See (Phys. Rev. **39,** 474 (1932)) and subsequent letter to the editor). Further evidence has been obtained that the depression of shot effect in pure electron space charge is given by

$$\frac{\bar{V}_s^2}{V_t^2} = f\left(\frac{i_0}{i}\right) = \left(\frac{\partial i_0}{\partial i}\right)^2_{E=\text{const}}$$

where i_0 is the space current collected at the anode and i the total emission current. i_0/i characterizes the space charge situation in the tube. It has been found expedient to represent this ratio by a new tube parameter P for which has been coined the term "*static receptance.*" Similar coefficients may be defined to refer to the limitation of current by space charge at each stage in its passage through the multi-electrode tube. (P_{cf}, the grid filament receptance, being the ratio of the electron current reaching the grid region to that emitted from the filaments, etc. A consistent convention has been adopted for the coefficient $\delta i_0/\delta i$; which might be called in conformity with established nomenclature the dynamic (or A.C.) receptance. Data will be presented extending the range of previous measurements on the dependence of the dynamic receptance upon the static receptance. This relation provides the basis for predictions of actual space charge fluctuation levels where experimental difficulties have prevented exact determination. These parameters, incidentally, seem to have some promise of becoming powerful tools in thermionic current analysis. Their properties are under further investigation.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

Industrial Building, Room 301

75. Photo electric emission from different metals. H. C. RENTSCHLER, D. E. HENRY AND K. O. SMITH. *Research Laboratory, Westinghouse Lamp Co., Bloomfield, N. J.*—A method was developed for preparing surfaces of any metal from which the photo electric sensitivity of the metal was measured. The metals tested are Thorium, Uranium, Titanium, Zirconium, Cerium, Tantalum, Tungsten, Copper, Silver, Magnesium, Aluminum, Cadmium, Zinc, Calcium and Barium. For Tungsten and Tantalum the values of the photo electric work function here obtained agree with the values of the Thermionic work function obtained by Dushman. For Thorium, Calcium, Uranium and Zirconium the values of the photo electric work function are considerably higher than the thermionic values for thin coatings of the corresponding metals on Tungsten. The photo electric threshold wave length for Barium metal is considerably shorter than that for Barium oxide coated cathodes commonly used in radio tubes and similar devices.

76. Mass spectrograph study of the ionization and dissociation of benzene by electron impact. ERNEST G. LINDER, *Cornell University.*—Benzene (C_6H_6) has been analyzed by a mass spectrograph designed especially for use with large molecules. Ions have been found containing carbon in amounts from C_6 to C_1, with various amounts of hydrogen attached. The principal primary ion for 120-volt electrons appears to be $C_6H_6^+$, this constituting about 50 percent of all the ions. The C_4 group makes up about 20 percent, and the C_3 group about 8 percent. By varying the pressure it has been shown that dissociation by collision with other molecules occurs, H atoms being stripped from the carbon ring. Molecules such as C_6H^+ and C_6^+ are apparently thus produced. No H^+ ions have been detected. The results confirm the stability of the benzene ring found in thermal dissociation studies. The ring does not break up under electron impact as readily as do straight chain molecules such as the n-paraffins studied with the mass spectrograph by Stewart and Olson (J.A.C.S., **53,** 1236 (1931)).

77. Probe measurements on arcs at atmospheric pressure. R. C. MASON, *Westinghouse Elec. & Mfg. Co., East Pittsburgh.*—Small probe wires, 5 to 20 mils in diameter, moving at constant velocity, were used to study a low current carbon arc in air at atmospheric pressure; the currents and voltages were recorded by an oscillograph. The arc voltage increased 3 to 12 volts maximum when the probe was in the arc, independent of the potential applied to the probe. The maximum increase in arc voltage, with probes of different sizes and shapes, did not vary greatly with probe velocity, between 10 and 100 cm./sec., but was an increasing function of the probe perimeter. A dark space, of diameter two to three times that of the probe wire, surrounded the probe, indicating that the state of ionization near the wire was not the same as in adjacent parts of the arc. As the space charge sheaths around the probe are smaller than the dark space, it seems probable that the usual Langmuir probe determination of space potential, ion density, and electron temperature (cf. Nottingham, Jour. Franklin Inst. 206, 43, (1928); 207, 299, (1929); Bramhall, Phil. Mag. 13, 682, (1932)) will not give the characteristics of an arc undisturbed by the measuring probe.

78. The intermediate free path case in the theory of a plasma. LEWI TONKS, *General Electric Co., Schenectady, N. Y.*—A theory of ion motions and potential distribution in the uniform positive column have been developed by Tonks and Langmuir, (Phys. Rev. **34**, 876 (1929)), for both the case where an ion generated in the gas falls without collision to the wall, and for the (Schottky) case where the ion velocity is proportional to field strength. The case of velocity α (field)$^{1/2}$ was touched upon but was thought to be unimportant. It now appears that in a mercury arc this neglected case is of prime importance from 5 to 30 baryes pressure and perhaps higher. From measurements of arc gradient, electron temperature, and positive ion current to the wall in the pressure range cited, values of arc current and electron density have been calculated which check with the more directly observed values in a fairly satisfactory way, and check far better than values calculated on either of the other two bases.

79. Further experimental data on the electrostatic and magnetic components in the electrodeless discharge. CHAS. T. KNIPP AND V. M. SMITH, *University of Illinois.*—About a year ago the senior author published photographs (Phys. Rev. **37**, 6 (1931)) showing the relative intensities of the discharge due to the two fields. These fields acted through the intervening glass walls of the discharge vessel. Since then four discharge tubes have been constructed of 12 liter Pyrex flasks, with *internal* energizing coils of No. 8 Cu wire placed as follows: First with a coil of 14 turns and 11 cm diameter, second with a coil of 7 turns similarly placed, third a coil of 1 turn, and fourth with no internal energizing coil. In addition to the above there was placed on the outside round the equator of each flask, with the plane parallel to the inner coil, an energizing coil of No. 10 flexible copper wire consisting of 3 turns. Switches were provided for making various connections. Thus the gas within a given flask could be excited at will, internally, externally, or with the exciting coils in conjunction, or in opposition. The four flasks were connected through the same manifold to a pressure gauge, and to the exhausting pumps. Liquid air traps were used and provision was made for introducing different gases. With this arrangement numerous photographs of the discharge were made which form the subject of this report.

80. The number of Langevin ions in the free atmosphere at Washington, D. C. G. R. WAIT AND O. W. TORRESON. *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—An apparatus for continuously recording the number of large ions in the free atmosphere has been in operation near the northern boundary of Rock Creek Park since the beginning of March, 1932. Ions having a mobility between 0.3 and 0.0004 cm/sec/volt/cm have been included in the count, experiment having shown that practically all Langevin ions in this locality have a mobility greater than the lower limit. The results from twelve complete days of observation of positive ions, give an average value of 5000 per cc. The average value for the day varies from about 2000 to 6000 per cc. The largest hourly value obtained since recording began is about 16000 per cc. A definite diurnal variation has been found, with two maxima, one shortly after sunrise and the other about twelve hours later, the average diurnal range being from about 3000 to 6000 per cc.

81. Features of the current-system of the upper atmosphere as revealed by the diurnal magnetic variations at Huancayo, Peru. A. G. McNish, *Department of Terrestrial Magnetism, Carnegie Institution. (Introduced by G. R. Wait.)*—The solar diurnal magnetic variation (designated by S) as recorded at the Huancayo, Peru, Magnetic Observatory of the Carnegie Institution of Washington, exhibits a marked difference from that computed for the Observatory from the spherical harmonic coefficients of S as derived by Chapman in 1919. Particularly, the observed north-force component of S exceeds this computed value by a factor of three. Assuming that S is due to currents flowing in the upper atmosphere, this difference is explained on the assumption of a more dense current-flow over the western hemisphere, with a particular crowding of the lines of flow over northern South America as is to be expected because of the southward displacement of the magnetic equator in the western hemisphere. Thus this apparent anomaly is quite consistent with the current-theory. On the other hand, if S is due to diamagnetic effects, as suggested by Gunn, the observed north component of S at Huancayo should exceed that computed from Chapman's coefficients by a factor of less than four-thirds, instead of a factor of three as is observed.

82. Ultra-violet transmission of the atmosphere. R. S. Rockwood, *University of New Mexico* and R. A. Sawyer, *University of Michigan.*—Using a thermocouple and a silvered corex filter, which transmits a narrow band of radiation near λ3200, observations have been made of the intensity of ultra-violet solar radiation reaching the earth. Simultaneous measurements were made on the campus of the University of New Mexico, altitude 5100 feet, and at stations at various altitudes up to 10,300 feet in nearby mountains. Data was taken on clear days in late fall when atmospheric conditions are most stable and the amount of water vapor is small and constant. The atmospheric absorption coefficients calculated for each observation were plotted for each altitude against the quantity of water in the light path, calculated from the observed vapor pressure by Hann's equation. Extrapolation to zero water gave an absorption coefficient for unit air mass which varied but little with altitude and agreed within the experimental accuracy with that calculated from Rayleigh's molecular scattering formula, indicating that in dry, clean air molecular scattering is sufficient to account for the depletion of solar radiation at λ3200.

83. Visibility in New York City. Morgan T. Riley, *National Conference Board on Sanitation. (Introduced by H. H. Sheldon.)*—As dust increases visibility decreases by the equation $583\mathrm{D}-1.1963-V=0$. As relative humidity increases visibility decreases by the equation $102.08-6.81V-\mathrm{H}=0$. The joint effect of dust and relative humidity was analyzed into their separate effects. The dust count was held constant and visibility measured at increasing relative humidities. In its turn relative humidity was held constant and visibility measured at increasing dust counts. Along a diagonal drawn through the table visibilities are equal with an addition of 10,000 dust particles per cubic foot and a subtraction of 10% relative humidity Above this diagonal subtraction of 10,000 dust and addition of 10% relative humidity gives a visibility that is better. Here therefore dust was more potent. Below the diagonal addition of 10% relative humidity and subtraction of 10,000 dust particles gave poorer visibilities. The proportion of days above the diagonal when dust was more important was 54.2%, of days below the line when relative humidity was more important was 37.0%, while 8.8% of the days found the addition of 10,000 dust particles per cubic foot and the subtraction of 10% relative humidity of equal effect upon visibility. These values can be made the measure of the success of a smoke campaign.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Bureau of Standards

East Building, Lecture Room

84. Diffusion technique for the separation of the isotopes of hydrogen. R. M. Langer, *University of Minnesota.*—It is easy after some experience with the problem to understand why Stern and Volmer (Ann. d. Physik **59**, 225, 1919) failed to find evidence for the isotope of

hydrogen recently discovered by Urey, Brickwedde and Murphy. Their technique can be very greatly improved and by a modification of their method it is hoped that an apparatus can be developed which will be more economical and more convenient than the counter-diffusion process favored by U., B. and M.,—at least for small increases in the concentration of the heavier isotope. By far the most promising permeable material is paper. The number κ of molecules of a gas of molecular weight M passing in one second through unit area of a paper sample subject to a pressure difference of 1 dyne/cm² can be fairly represented by the sum $\kappa=\alpha/(M)^{1/2}+\lambda$ where α and λ are practically independent of M. The first term is the desirable diffusion component and the second a wasteful leak. At atmospheric pressure in H_2 a typical bond paper might have a value of $\kappa=10^{12}$. Of this λ might be about 25%. Other papers have sometimes a hundred times smaller value of κ and nevertheless about the same value of λ/κ. Other substances such as rubber, cellophane, parchment, porcelain are practically hopeless for several reasons, besides being exceedingly slow compared with paper.

85. Helium filled G. M. tube counters. J. A. BEARDEN AND C. L. HAINES, *Johns Hopkins University.*—The operation of the Geiger-Muller tube counter filled with air at a pressure of 3 to 7 cm of mercury is well known. In the present work it has been found that similarly constructed counters filled with helium at pressures from 10 to 76 cm of mercury will operate at slightly higher voltages. The sensitivity of the helium filled counters for gamma-rays appears to be somewhat higher than that of the air filled counters. The principal advantages of the present counters are: first, counters can be constructed using extremely thin windows for recording α and β-rays; second, by using a low helium pressure the counters will operate at a very low voltage; third, the range of the working voltage is greater. Counters have been operated for several weeks without any change in sensitivity or operating voltage. It has also been found that a single stage amplifier connected to a cathode ray tube is a satisfactory method for observing the counts.

86. A cloud expansion chamber for automatically photographing the tracks of corpuscular cosmic rays. THOMAS H. JOHNSON, WILLIS FLEISCHER, JR. AND J. C. STREET, *Bartol Research Foundation of the Franklin Institute.*—An expansion chamber of new design, operating continuously, is illuminated by photoflash lamps exploded by the coincident discharge of two Geiger-Mueller counters placed above and below the chamber. (See Abstract No. 87 of this program.) The illumination takes place only if the coincident discharge of the counters occurs during the sensitive interval of the chamber. The circuits are arranged so that the sensitive period as well as the delay of the flash after the coincidence can be varied. A large percentage of the photographs obtained with this apparatus contain straight tracks in the line of the counters. The chamber operates at pressures above atmospheric with controls on both expansion ratio and rate of expansion. The laboratory supply of compressed air with a device for accurately controlling the pressure is used to operate the chamber. Three chambers operating simultaneously are being constructed for studying cosmic ray tracks over extended lengths of their paths.

87. Experiments on the corpuscular cosmic radiation. J. C. STREET AND THOMAS H. JOHNSON, *Bartol Research Foundation of The Franklin Institute.*—A new vacuum-tube circuit for recording coincident discharges of two or more Geiger-Mueller counters has been developed with improvements as regards the sensitivity, resolving time and variability of counting rate. The number of accidental coincidences from two counters having individual counting rates of 90 per minute is $2.5\neq0.5$ per hour, corresponding to a resolving time $\tau=1.5\times10^{-4}$ secs. The number of real coincidences corresponds to 7.3×10^{-3} per cm² per unit solid angle per

Cm. of lead	0	1	2	5	8
Coincidences per min.	$1.61\neq.03$	$1.68\neq.03$	$1.64\neq.03$	$1.54\neq.02$	$1.45\neq.03$
Per cent change due to lead	—	+4.4	+1.5	−4.4	−10

second with uncertainties because of end effects and an unknown but finite recovery time of the counters. This is from two to three times the number reported by former observers and yields the more satisfactory value of 98 ions per centimeter of path when used in conjunction with Millikan's latest value of the ionization in an electroscope. The effect of lead placed above the counters has been measured with the results and probable errors shown in the table. The increase with small thicknesses of lead is in agreement with Schindler. The ratio of coincidences at 45° to those in the vertical direction is $0.41 \neq 0.04$.

(The authors hope to demonstrate a new portable apparatus making a continuous record of the cosmic radiation throughout the period of the meetings.)

88. The direct detection of individual cosmic rays. W. F. G. SWANN AND J. C. STREET, *Bartol Research Foundation of The Franklin Institute.*—The cosmic-ray ionization current was measured in an iron tube 15 feet long, 6 inches internal diameter, filled with nitrogen to a high pressure, and with suitable devices for compensating potential fluctuations and for balancing out the main part of the ionization current. Data for the ionization by a single cosmic ray vary from 20 to 250 ions per centimeter of path. On the basis of 100 ions per centimeter of path, a cosmic ray, traveling the whole length of the above tube, would produce about 4×10^6 ions, and would result in a spurt of ionization current twenty times that caused by an alpha particle, so that it would be distinguishable unambiguously from such spurts. Data obtained from Geiger counters have indicated that 7×10^{-3} cosmic rays pass through one square centimeter per second, having come within unit solid angle. On this basis, the above tube should show spurts corresponding to cosmic rays traveling the whole length, about 4 times per hour. Such spurts have been observed and recorded in about the expected amount and frequency. Associated with them, moreover, are a few spurts of larger amounts, having characteristics suggestive of their source having originated in the gas.

89. Diffraction of low-speed electrons by a gold crystal. H. E. FARNSWORTH, *Brown University.*—A previous investigation of electron diffraction by a silver crystal, for normal incidence on a (100) face (to appear shortly in Phys. Rev.), showed that, in general, each observed diffraction beam, between 0 and 325 volts, is made up of several components of fine structure. As the angle of incidence was changed from normal in small steps, the relative intensities of the components of any one beam changed enormously. The components which are present for normal incidence may disappear and others appear at angles of incidence a few degrees from normal. For each beam there is a certain angle of incidence at which the most intense component attains its maximum value. No exact correspondence between the characteristics of the various beams was found. We are now obtaining similar observations for a gold crystal. A fine structure is also observed for these beams. The intensities of the components are also very sensitive to a change in the angle of incidence, but the particular characteristics of any one beam differ considerably from those of the corresponding beam for silver. This is particularly significant since gold and silver have the same lattice structure and also the same lattice constants to within 0.4 percent.

90. Reflection of molecular beams of the rare gases from alkali halide crystals. R. M. ZABEL, *University of Iowa.*—Evidence of diffraction phenomena has been found in the reflection of helium from sodium chloride crystals in agreement with the results obtained by Estermann and Stern (Zeit. f. Phy. **61,** 95, (1930)). Argon reflected from sodium chloride gives a diffuse reflected beam closer to the normal than the expected position of a specular beam. The results obtained in the reflection of argon from sodium chloride are similar to those obtained for mercury reflected from the same surface by Zahl and Ellett (Phys. Rev. **38,** 977 (1931)). Present evidence indicates that argon incident upon lithium fluoride gives rise to relatively less directed and more diffuse scattering than it does when incident upon sodium chloride.

91. Reflection of mercury atoms from lithium fluoride crystals. R. R. HANCOX AND A. ELLETT, *State University of Iowa.*—The scattering of a molecular beam of mercury by a lithium fluoride crystal is studied as a function of crystal and beam temperature. A quasi-specular beam of the type observed by Zahl (H. A. Zahl, Phys. Rev., pp. 977, Vol. 38 (1931)) for other alkali halide crystals is obtained here, with the same characteristic temperature changes.

92. Reflection of beams of Tl, Sb, and Pb from a sodium chloride crystal.—J. M. B. KELLOGG, *State University of Iowa.*—Directed beams of atoms of Tl, Sb, and Pb reflected from a freshly cleaved crystal surface of Sodium Chloride have been observed. In the case of Tl, Pb, and Sb at small angles of incidence the reflection is specular. For Sb incident at a grazing angle of 50° the reflected beam shows a deviation from the specular path in a direction away from the normal.

93. Mean free paths of gases. JOHN A. ELDRIDGE, *State University of Iowa.*—A molecular beam passes through a chamber enclosing gas at low pressure. The emergent beam is measured on a Pirani gauge. The question has been raised whether a collision in the classical sense has any meaning, without specification of the angle of scattering considered. As a preliminary experiment it was determined that the molecules suffering very small deviations (less than a degree) were negligible in number. The mean free paths of H_2, He, N_2, O_2, molecules have been measured; in each case the values found are smaller (by several fold) than the values determined indirectly from kinetic theory. The difference is probably due to neglect of the persistence of velocity in the kinetic theory.

94. Motion of K^+ ions in mercury vapor. CARL FRISCHE, *State University of Iowa.*—Ionization by positive ion impact was studied in A, Ne, N_2, CO, and He at voltages up to 4000 volts and the results seem to check with those of Sutton, (Phys. Rev., **33**, 363 (1929)) and Beeck (Ann. d. Phys. **6**, 8, 1001, (1930)), where ever a check was possible. When the work was extended to an element heavier than K^+ i.e., mercury, the results are more complicated. The evidence seems to indicate; (a) reflection of K^+ ions at all voltages, (b) an increase in mean free path with increase in voltage, (c) no ionization below 250 volts but above 250–350 volts ionization increases with the voltage.

SATURDAY MORNING 10:00 TO 11:15 O'CLOCK

National Academy of Sciences

Auditorium

SYMPOSIUM

on

"Electric and Magnetic Units"

Program arranged by A. E. Kennelly on behalf of The International Electrotechnical Union and the International Union of Pure and Applied Physics

Contributed Papers

95. Magnetic units. A. E. KENNELLY, *Harvard University.*—The International Electrotechnical Commission (I.E.C.) through its Advisory Committee on *Nomenclature*, after three years of international discussion over certain perplexing ambiguities, all over the world, in the use of the C.G.S. magnetic unit names, brought in a unanimous report to the I.E.C. Plenary Meeting at Oslo, in 1930, recommending the following names for C.G.S. magnetic units: ***gilbert*** for magnetomotive force f, ***oersted*** for magnetizing force H, ***maxwell*** for flux Φ, and ***gauss*** for flux density B. The Oslo meeting accepted these recommendations unanimously. At an international committee meeting in London, last September, they were reviewed and reindorsed. It would seem that if these resolutions continue to be generally accepted, the confusion that has existed in C.G.S. magnetic unitology, for over thirty years, should be ended. Practically all magnetic literature, at present, is written in C.G.S. magnetic units, but demands of lesser urgency have been made for completing the practical, or *volt-ampere-ohm* system of units in the magnetic series. This is a matter in which the I.E.C. has expressed a desire that the International Physical Union (I.P.U.) should participate. It is hoped that the American Physical Society may formulate opinions on this difficult question, which can only

be finally settled by international agreement. Two outstanding questions seem to stand in the way of assigning further unit magnitudes in the practical magnetic system: (a) Should the system be "subrationalized?" Specifically, should the mmf of a coil of N turns, carrying a steady current of I amperes, be $4\pi NI$, or simply NI? (b) Should the flux density B be referred to the square quadrant, the square meter, or the square centimeter? On both of these questions there is much difference of opinion in all countries. Arguments are presented on both sides.

96. Electromagnetic equations and systems of units. LEIGH PAGE, *Yale University.*—Most of the suggestions for a more convenient system of electrical units have ignored the far more important question of the form of the fundamental equations of electromagnetism. These equations are written in their most general form and the following criteria are proposed: (1) There should be only *one* set of fundamental equations in place of the three or four used at present; (2) There should be two systems of units, one c.g.s. for the physicist and one practical for the engineer, both systems using the *same* set of fundamental equations; (3) The eight internationally recognized units (joule, watt, coulomb, ampere, volt, ohm, farad, henry) should be retained in the practical system; (4) The fundamental equations should be symmetrical in form. It is shown that these criteria can be fulfilled in an infinite variety of ways, of which the simplest is that which employs the Heaviside-Lorentz set of equations. For this set of equations the eight internationally recognized units are retained in the practical system provided $\epsilon^{-4}(10)^{-19}$ gm, $\epsilon^{2}(10)^{12}$ cm, and 1 sec are chosen as units of mass, length, and time respectively, where $\epsilon \equiv 1.06275$. The system of units proposed by Kennelly (Proc. Nat. Acad. Sci. **17**, 147 (1931)) is shown to lead to a much more complicated set of fundamental equations.

97. A general theory of electric and magnetic units. VLADIMIR KARAPETOFF, *Cornell University.*—The fundamental electric, magnetic, and electromagnetic relationships may be written in a general system of units such that they may be obtained in any existing or future system of units by assigning certain values to five parameters (which have nothing to do with the choice of units of length, mass, or time). These parameters are as follows: (1) The ratio between the actual electrostatic flux and the so-called geometric flux; (2) Same for the magnetic flux; (3) A factor which converts a volume of current into the corresponding m.m.f.; (4) The absolute permittivity of vacuum; (5) The absolute permeability of vacuum. These five parameters must satisfy the condition that the velocity of electromagnetic waves in vacuum is a given quantity. A choice of four parameters fixes a type of system of units; by assigning some definite values to three non-electrical quantities, for example, units of length, time, and mass, a specific system of that type is obtained. A new system of units may be devised out of the general system, to satisfy some given specifications. The complete paper has been accepted for presentation before the American Institute of Electrical Engineers and is to be published in their Transactions.

98. Three superfluous systems of electromagnetic units. GEORGE A. CAMPBELL, *American Telephone and Telegraph Co., New York.*—In Nature, for March 5, a reviewer says: "Future students will apparently have to learn not only the electromagnetic and the electrostatic systems of units, but also the Heaviside-Lorentz system." These three systems are added to the practical system. Would it not be far better for future students to learn that they will need but one system of units for both practical and theoretical work as engineers or scientists; that this universal system includes the meter, second, watt, volt, and other basic units which they have been using as home electricians and radio amateurs; that when they come to read the older electromagnetic literature, it will be unnecessary to learn to use the three obsolete systems of units, because it will be simpler to translate anomalous units into the one comprehensive, coherent system by using a conversion table? Since the answers seem to be emphatically in the affirmative, it follows that international magnetic units should be added to the mechanical and electrical units to form a complete, rational system, coherent with the meter, kilogram, second and international ohm. It would be most unfortunate if transition difficulties, real or imaginary, are allowed to discourage the early formulation of supporting opinion.

SATURDAY MORNING 11:15 TO 12:30 O'CLOCK

National Academy of Sciences

Auditorium

SYMPOSIUM

on

"Structure of Solids"

Invited Papers

99. The Mosaic Structure in Metal Crystals. G. GOETZ, *California Institute of Technology.*

40 minutes.

100. On Newly Discovered Effects in Ferromagnetic Crystals. FRANCIS BITTER, *Westinghouse Elec. & Mfg. Co.*

25 minutes.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

National Academy of Sciences

Auditorium

Paper No. 108 will be read by title.

101. Hall effect versus intensity of magnetization. EMERSON M. PUGH AND T. W. LIPPERT, *Carnegie Institute of Technology.*—Previously reported work has shown that in two ferromagnetic materials, the Hall e.m.f. is a linear function of the intensity of magnetization (B-H), rather than of B or H alone. Recent investigations employing much improved apparatus with consequently increased accuracy show that such a linear relationship is definite in four additional materials, whether the specimen was annealed, quenched or baked, both on the virgin curve and on all succeeding hysteresis loops. This relation is particularly striking in the case of a slightly ferromagnetic alloy (Fe 70%, Ni 30%) in which the H was sometimes more than half of B, whereas in other materials H was never more than 5% of B. To obtain the required accuracy it was necessary to employ a new method of determining H.

102. Kerr effect and molecular field in rochelle salt. HANS MÜLLER, *Massachusetts Institute of Technology.*—Measurements of the Kerr Effect in Rochelle Salt between −20°C and 25°C give for fields above 200 volt/cm a linear relation between change of double refraction and electric field in the a-direction of the crystal, though reversing the field does not reverse the effect. This behaviour can be explained with help of the electric field of the oriented dipoles which are responsible for the anomalous dielectric properties. With a field of 200 volt/cm the orientation and the molecular field reach saturation. The molecular field is very large compared to the applied fields and since the Kerr effect is proportional to the square of the sum of both fields the effect appears to be linear with the applied field. From the data we estimate a molecular field of 4–8 million volt/cm and a "true" Kerr constant between 10^{-11} and 2×10^{-11} cm³/erg, both varying with temperature. These values are of a reasonable order of magnitude. The molecular field corresponds to an average distance of 4 A between the dipoles, while the average distance between the water molecules in the crystal is 4.04 A.

103. The variation in the Kerr electro-optical constant of nitrobenzene with temperature near a transition point. (9.6°C.) HERBERT TROTTER, JR., *University of Virginia* (*Introduced by J. W. Beams*).—Wolfke and Mazur (Nature **127,** 741 (1931); **128,** 584 (1931)) have observed a distinct transition point in liquid nitrobenzene at 9.6°C. They note an abrupt change in refractive index, dielectric constant, and slope of the density curve. G. W. Stewart (Phys. Rev., A, **39,** 176 (1932)) also has noted a change in the x-ray diffraction at about this tempera-

ture. The author has found a similar change in the Kerr constant at about this point. The method used was a relative one. Light of a narrow range of wave-length was passed through two Kerr cells at right angles, one of the cells being at a fixed, the other at a variable temperature; and potentials on the cells were adjusted to secure compensation. The square of the potential ratio, assuming Kerr's law, varies inversely as the ratio of the Kerr constants. Impulsive potentials (less than 10^{-4} sec) were used to avoid both heating and possible distortion of the electric field.

104. Magneto-optic rotation by condenser discharge. FRANCIS G. SLACK AND W. M. BREAZEALE, *Vanderbilt University.*—The rotation of the plane of polarization of light produced by a condenser discharge across a spark gap has been measured when the condenser discharges through a coil surrounding various media of comparatively high Verdet Constants. The set up is similar to that used by Dr. Fred Allison (J.A.C.S. 52, 3796 (1930)) except that a Lippich double field polarimeter replaces the crossed nicols. Net rotations, positive and negative, are found depending on the material in the field and on the constants of the discharge circuit. These rotations are not found to depend on the length of the wire path leading to the coil unless this materially changes the resistance in the circuit with resulting change of wave form. Curves are obtained showing the variation in rotation with resistance, capacity, and inductance in the circuit. An unexpected and as yet unexplained phenomena appears in that with reversal of relative direction of net field and direction of light, all other factors held constant, the rotation in the positive or clockwise direction is greater than that in the opposite direction. Efforts to eliminate this asymmetry have to date been unsuccessful. This effect has been found for all materials used including carbon bisulphide, toluene, chloroform, and water.

105. Nature of the phenomena underlying the magneto-optic method of analysis. FRED ALLISON, J. H. CHRISTENSEN AND GEORGE V. WALDO, *Alabama Polytechnic Institute.*—For several years investigations have been in progress in this laboratory concerning the nature of the physical phenomena which produce the minima of light characteristic of compounds in the magneto-optic method of analysis. (Allison, Ind. Eng. Chem. (Analyt. Ed.), **4,** 9 (1932)). The following theories have been tested experimentally and found inadequate: (a) electrostatic effects; (b) effects due to scattering, absorption, depolarization, etc.; (c) transverse magnetic field effects; (d) effects characteristic of the applied magnetic field itself; (e) poor contacts in trolley system and electrical interference. That the phenomena are to be explained on the basis of a time lag in the Faraday effect seems to be indicated from the results of various experiments, namely: the minima are observed with the Nicols (a) crossed and the magnetic fields opposing in the two liquids; (b) completely uncrossed and the fields assisting; (c) uncrossed at any angle (not approaching $\neq 90°$), fields opposing. Maxima are observed with Nicols (d) crossed, fields assisting; (e) completely uncrossed, fields opposing. With fields assisting, when the analyzing Nicol is rotated from the crossed position to angles (f) in the direction of the magnetic rotation, minima are observed; (g) in the direction opposite to the magnetic rotation, maxima are observed. The minima and maxima coincide for any given compound. In uncrossed settings of Nicols, a third Nicol serves to reduce the light to the required intensity.

106. The magnetic qualities of large artificial graphite crystals. ALEXANDER GOETZ AND ALFRED FAESSLER. *California Institute of Technology.*—A process applicable to any crystalline substance showing magnetic anisotropies has been developed. It permits to measure susceptibilities in different directions with regard to the crystallographic axis for crystals down to ultramicroscopic sizes. The process consists of settling the crystal powder of equally sized particles in a liquid gelatine solution within the field of a strong electromagnet. After each particle has oriented itself by turning its most paramagnetic direction parallel to the lines of force, the solution is solidified by cooling and each particle thus is fixed in an isolated but crystallographically parallel position with regard to its neighbor. The diamagnetic properties of graphite powders are investigated and the critical size below which the crystal diamagnetism begins to depend on the size of the individual crystal as well as the dependence of this critical size on the field strength were studied. The magnetic anisotropy of these crystals are approxi-

mately 28, i.e. 4–5 times larger than the values obtained from natural graphite single crystals. The experiments seem to give definite proof that the crystal diamagnetism is caused by "free" electrons with large paths.

107. Magnetic discontinuities produced by mechanical deformation. DAVID G. C. LUCK, *Massachusetts Institute of Technology.*—The magnetic discontinuities produced by mechanical deformation of various ferromagnetic materials in small magnetic fields have been studied oscillographically. These discontinuities have been found to be largely uneffected by external magnetic field as long as this is small. Soft substances which have high permeability and positive magnetostriction in general show large discontinuities, the magnitude of which varies little between quite different substances. Substances which are hard or have low permeability or negative magnetostriction in general show no discontinuities. The amplitude of the discontinuities depends mainly on the rate of mechanical deformation, both for tension and for torsion of the sample, and is much greater for the first deformation cycle after annealing than for succeeding deformations. The effect seems to be distinctly an elastic one, vanishing when plastic deformation sets in. It vanishes also if the sample is heated to the Curie temperature. This behavior of ferromagnetic material seems explicable on the basis of the Akulov theory of ferromagnetism.

108. The contribution of free electrons to ferromagnetism. CAROL G. MONTGOMERY, *Sloane Physics Laboratory, Yale University.*—The recent experiments of Dorfmann and others (Zeits. für Physik **70,** 796 (1931)) have again raised the question whether free electrons contribute to ferromagnetism. The specific heat of the free electrons measured by thermoelectric data and the calorimetric specific heat both undergo anomalous variations at the Curie point, but the exact connection is not clearly understood. As first pointed out by Duhem in 1888, if free electrons were directly responsible for ferromagnetism, then when one end of a piece of iron is in a stronger magnetic field than the other, there would be a concentration of electrons in that end. This would produce a difference in potential between the ends given by the relation $V=-W\lambda$ where λ is the electrochemical equivalent and W the difference in energy of magnetization per gram. An attempt made to find such an effect in iron using a sensitive galvanometer and an accurate thermostat showed that the effect was less than 5×10^{-10} volts for a field of 15,900 gauss. The potential difference computed by the above expression is of the order of 10^{-4} volts. This seems to indicate definitely that free electrons are not directly responsible for ferromagnetism. The analogous effect for dia- and paramagnetics is below the limits of these measurements, but as Bitter has pointed out (Phys. Rev. **36,** 978 (1930)) it should be accessible in some cases.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

National Academy of Sciences

Lecture Hall

109. Line reversal temperature measurements on an internal combustion engine. A. E. HERSHEY AND R. F. PATON, *University of Illinois.*—Engine flame temperatures have been determined by one of the authors (results to appear in Ind. and Eng. Chem.) from radiation measurements with a thermopile calibrated as a radiation pyrometer and absorption measurements by the method of Schmidt (Ann. der Phys., **29,** 998, (1909)), assuming radiation with, only thermal excitation. Since chemiluminescence makes such an assumption open to question flame temperatures have now been found by line reversal. Other investigators have used this method for a satisfactory determination of continuous flame temperatures, notably Griffiths and Awberry (Proc. Roy. Soc., **123,** 401, (1929)). Continuous radiation is passed through the flame into which Na has been introduced, the intensity of the continuous radiation being varied until the superimposed *D* line just disappears. The brightness temperature of the source of continuous radiation, found with an optical pyrometer, is, with certain corrections, equal to the flame temperature. A stroboscopic shutter permits comparison during $2\frac{1}{2}$ degrees of

crank travel at the same point in successive cycles. Temperatures found by the two methods agree satisfactorily. With theoretical air-fuel ratio the maximum temperature from radiation measurements was 2373°K and from line reversal measurements 2310°K, indicating that the effect of chemiluminescence on radiation temperature measurements is negligible.

110. Development of polar characteristics in insulating oils. W. N. STOOPS, *Westinghouse Elec. & Mfg. Co., East Pittsburgh.*— (*Introduced by Chas. F. Hill.*)—The decomposition of transformer oils may be followed quite closely by measuring the dielectric constants of the oils as they deteriorate in service. The change in dielectric constant of an oil depends both on the length of time it has been in service and on the chemical composition of the oil, so that it is possible to distinguish between the decomposition rates of different oils. These data are compared with those obtained on the same oils decomposed very much more rapidly in laboratory tests. The change in dielectric constant is definitely correlated with the change in chemical characteristics. That the change in dielectric constant of the oils is due to the formation of polar molecules is shown by a study of the variation of the dielectric constant and power factor of the decomposed oils with temperature and frequency.

111. Behavior of the copper-cuprous-oxide rectifier at high frequencies. W. P. PLACE, *Union Switch & Signal Company, Swissvale, Pennsylvania.* (*Introduced by L. O. Grondahl.*)—It has been found experimentally that the copper-cuprous-oxide rectifier, which behaves as an asymmetric resistance at ordinary commercial frequencies, has a considerable capacity at the rectifying boundary which impairs its rectifying properties at higher frequencies. This effect of the capacity on the rectifying properties is due to the fact that its impedance at the high frequencies is low enough to become comparable with the resistances of the rectifying boundary. At high frequencies the capacity impedance may be considerably lower than the reverse current resistance, and at low current densities may even be low compared to the forward resistance. By increasing the voltage across the rectifier, the forward resistance can be lowered to such an extent that even at high frequencies it becomes small compared to the capacitance. When this condition exists, the rectifier functions satisfactorily. An analysis with the help of equivalent circuits is presented to illustrate the effect of the static capacity on the rectifying properties of a bridge-type rectifier circuit. Curves, both calculated and experimental, showing the relation between a-c and d-c voltages at different impressed voltages and for different frequencies are given.

112. A method of measuring the short-time D. C. Conductivity of insulating liquids. G. W. GARDINER, JR., *Bureau of Standards, Washington, D. C.*—The method consists in comparing the short-time direct current through a test condenser containing the liquid with that through a guard ring air condenser of negligible conductance. In order to eliminate the displacement current, the comparison is made in a bridge having the two condensers in adjacent arms and resistance in the other two arms. The bridge is first balanced with an alternating current source, which is then replaced by a direct current source controlled by a commutator by means of which the direct current potential may be applied once a second for a time which may be varied from 0.002 to 0.500 seconds. The change in potential per cycle of the midpoint of the two condensers, as determined by a sensitive direct current amplifier measures the average irreversible component of the current through the liquid during the time of application of the field.

113. Conductivity of liquid mercury at high temperatures and pressures. FRANCIS BIRCH, *Jefferson Physical Laboratory, Harvard University.*—The electrical conductivity of liquid mercury has been measured in the region between 0 and 1100 degrees centigrade, and from 1 to 4000 atmospheres. In this region the specific resistance increases with temperature, and decreases with rising pressure. Taking the specific resistance at 0 and 1 atm. as 1.00, the resistance at 1100° and 1000 atm. is about 4.5, at 1100° and 4000 atm. about 2.9. Both $1/\rho(\partial\rho/\partial T)_p$ and $1/\rho(\partial\rho/\partial p)_T$ decrease as p increases, and increase as T increases. The boiling curve of mercury has been retraced, by an electrical method, and indications found of the liquid-vapor critical point, at about 1460°C and 1600 atmospheres. The criterion applied was the continuous variation of resistance with increasing temperature, at constant pressure.

114. The electrical conductivity of silicon carbide. R. W. SEARS AND J. A. BECKER, *Bell Telephone Laboratories, Inc.*—By measuring the potential between several metallic point probes with a vacuum tube potentiometer, the conduction in crystals of silicon carbide has been shown to obey Ohm's law. Specific resistance of a black opaque crystal was found to be 2.13 ohm cm while for a semi-transparent green crystal it was 0.41 ohm cm. The resistance is independent of direction of current flow. The rectification and non-linearity exhibited by over-all current-voltage curves between two contacts on these crystals resides in the large potential drop at the contact junctions. Exploration of various crystal surfaces with a needle-point contact showed that the resistance of this contact varies greatly from one portion of a surface to another and from crystal to crystal. A 0.002 cm displacement of the point contact on smooth surfaces sometimes caused the resistance to change by factors as large as 10,000 while on others it was fairly uniform over large areas. Momentarily applying a large voltage across the contact greatly reduces its resistance and makes it ohmic for small currents.

115. Potential distributions in large cylindrical discs with partially penetrating electrodes. MORRIS MUSKAT, *Gulf Research Laboratory.*—The equivalence of the fluid pressure in a liquid bearing sand to a velocity potential gives practical significance to the potential problem of a conducting electrode partially penetrating a large cylindrical disc. A detailed investigation has been made of the potential distributions in such discs for various degrees of electrode penetration. Separate formulas were derived for studying the potential very near the electrode and at large distances from it. An approximation method was developed for determining the proper flux distribution along the electrode surface so as to make its potential uniform. The resistances of the disc for various electrode penetrations and disc thicknesses were computed and a semi-empirical approximation developed for evaluating the resistance without the necessity of going through the details of the analysis.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session held in the East Building at the Bureau of Standards on Thursday and Friday and in the Auditorium at the National Academy of Sciences on Saturday after the completion of the regular program for the session.

116. Some physical properties of compressed hydrogen. W. EDWARDS DEMING AND LOLA E. SHUPE, *Bureau of Chemistry and Soils, Washington, D. C.*—The compressibility data on hydrogen taken at the Reichsanstalt, the Leiden and the Fixed Nitrogen Research Laboratories are smoothed and extrapolated to cover the range −215°C to 500°C, and to 1200 atmospheres pressure. A sensitive graphical method is used for obtaining derivatives, and these with certain thermodynamic relations give physical properties of the gas. The properties so calculated are temperature and pressure expansion coefficients, fugacity, heat capacities at constant pressure and volume and the Joule-Thomson coefficient. It was not possible to extend calculations on heat capacities and the Joule-Thomson coefficient below −75°C. The physical properties that are calculated by this method are listed in a table or shown by graphs. The change in C_p at −75°C amounts to 0.95 cal/mole degree over the 1200 atmosphere pressure range. At higher temperatures, pressure causes a much smaller change; at 500°C, C_p increases only 0.08 as the pressure is increased to 1200 atmospheres. C_v at 25, 50, 75, $\cdots$, 800 atmospheres increases rapidly with temperature from −75° to 100° and thereafter increases slower. The Joule-Thomson coefficient is negative from −75° to 500° up to 1200 atmospheres.